20 UNDER 40

Today's faculty are powered by ideas – in the classroom and the lab.

By Sarah Khan, Mary Lord, and Mark Matthews

They hail from across the United States and beyond, migrating to engineering education via pathways as far flung as an entrepreneurial start-up, competitive gymnastics, medicine, and the Navy. Their research topics are equally varied, from cancer to energy storage and a field so rarefied – nanogeochemistry – that its Facebook page has just four "Likes."

What these accomplished under-40 academics all share, however, is a demonstrated talent for teaching, real-world research, or – as is often the case – both. They were picked to highlight the role of engineering and engineering technology institutions in shaping a globally competitive workforce, based on recommendations by schools and colleagues and research by *Prism* staff. The 20 individuals profiled on the following pages are not a scientific sample. Rather, they represent a balance of geography, discipline, and type of institution. The common denominator is imagination.

Take Micah Stickel of the University of Toronto, one of the inventive young instructors transforming classroom practice. One of the first at his school to ditch the blackboard and teach from a tablet, he now is overseeing a review and revision of the freshman experience. While Stickel and physician-engineer Sujata Bhatia of Harvard are foregoing the research-oriented tenure track to concentrate on teaching and advising, Jim Pfaendtner, an assistant professor of chemical engineering at the University of Washington, is proof that great teaching need not be in zero-sum competition with research. Besides award-winning work on optimizing energy production from biomass, he routinely earns course evaluations that exceed the 5-point scale – a reflection of his commitment to mentoring and helping students, particularly women and underrepresented minorities, navigate the career maze. "I believe really strongly in the power of the university to change people's lives," he says.

Another driver of change is outreach. Stephanie Luster-Teasley, a chemical engineer at North Carolina A&T State University with appointments in civil, biomedical, and environmental engineering, runs a summer lab experience for African -American girls that has grown so popular she is launching a similar program for boys.

Looming large through these stories is government funding, particularly money that offers a leg up for young faculty struggling to see their ideas bear fruit in the lab. It's a safe bet the pathbreaking work described here, in such areas as earthquake-resistant construction, nuclear weapons detection, neuroimaging, and women's reproductive health, wouldn't have happened without the basic research dollars that flow from the National Science Foundation, the Department of Defense, and other government agencies.

Design by Nicola Nittoli / Photograph by NASA

Abbie Liel

SEISMIC DAMAGE CONTROL


Image Courtesy of Abbie Liel

When Abbie Liel arrived in L'Aquila, Italy, in April 2009, aftershocks could still be felt from a 6.3-magnitude earthquake that had killed 305 people, injured at least 1,500, and left 30,000 homeless. Examining 483 buildings in a two-year study, Liel and her colleagues at the University of Colorado, Boulder documented a major reason for the human toll: Most of the city's concrete buildings were more than two decades old and lacked the tremor-resistant features of more modern designs.

A structural engineer who has always loved applying math and science to human problems, Liel is a leading researcher at the intersection of construction, risk assessment, and public policy. She zeroes in with precision on the "weak links" most likely to cause serious damage or casualties in an earthquake so owners and planners can make cost-effective retrofits, mitigate hazards, and rebuild wisely.

In L'Aquila and in temblor-prone California, where Liel earned a Ph.D. at Stanford on a National Science Foundation fellowship, a common problem is nonductile – brittle – concrete-frame buildings, which she calculates are 35 times as prone to collapse as recent, more deformable structures. But reconstruction is costly. That's where "performance-based earthquake engineering" comes in. Simulating ground-shaking intensity and damage severity, it can assess which buildings in a community require retrofits based on their risk of collapse and the likelihood of resultant casualties. Such measurements would be impossible without the computational advances of the past five years, Liel says, and occasional use of CU's supercomputer.

Her methods could lend credibility to risk assessments in other seismic zones in addition to California, including the Pacific Northwest, Alaska, and Memphis, Tenn., which in the early 1800s experienced the biggest earthquake in U.S. history. Beyond earthquakes, the same tools can assist building owners and policymakers in flood zones. Hence Liel's newest project: an interdisciplinary exploration of how to win community acceptance of probabilistic damage models in Boulder, Colo., which witnessed disastrous flooding last year.

Richard Radke

SPECIAL EFFECTS ENGINEER


Image Courtesy of Richard Radke

Few engineering academics find grist for their research, let alone for a 409-page textbook, in Hollywood blockbusters, but Richard Radke has found both. A specialist in such computer-vision techniques as camera tracking, 3-D reconstruction, and face and body-motion capture, he refines tools developed for the big screen – shifting a character's image from a background shot to a new scene, for instance – to an expanding field of applications. These range from algorithms that provide a near-human reading of audio and video to locating individuals in a dense crowd and having industrial robots perform advanced tasks.

Radke looked on with envy as his Rice University roommate researched computer graphics in film and entertainment. As a hobby, he began steering his own interest in computer vision, video surveillance intelligence, and digital cameras toward movies and television. By the time he finished his electrical engineering Ph.D. at Princeton, his hobby had become a career.

So important have graphics and video become to industry, science, and national security that Radke is one of the most active researchers at Rensselaer Polytechnic Institute, where at 39 he is already a full professor in the Department of Electrical, Computer, and Systems Engineering. Boosted by a 2003 NSF CAREER award, he now pulls in $650,000 a year in grants, including from the Department of Homeland Security and National Institutes of Health. He's also part of the RPI-headquartered NSF Smart Lighting Engineering Research Center.

The silver screen, Radke finds, offers the perfect introduction to teaching computer vision. "Everyone watches television and goes to the movies, so it's a good motivator to learn about the fundamentals of computer vision," he says. His textbook, *Computer Vision for Visual Effects*, shows readers the theory behind Hollywood engineering and a glimpse of what it's like to work in such an industry.

Highly rated by students – one dubbed him "God, with chalk" on an evaluation form – Radke says the "old school" blackboards and lecture halls still work for his classes, but he injects detailed digital figures and uses open, anonymous forums to make the students more comfortable about asking questions and getting feedback.

Adam Lee

PRIVACY PROTECTOR

Image Courtesy of Adam J. Lee


Even a few years ago, Adam Lee found it easy to advise University of Pittsburgh students on how to guard their laptops against remote-access snoops and tracking software: Set up standard firewalls, and don't install unfamiliar programs. By now, the explosion of social media and advent of cloud computing and sensor-studded mobile technologies make personal data much harder to protect. But Lee, a Pitt assistant professor of computer science, is keeping pace, looking for new ways to help people stay secure in their online worlds.

Part of the answer lies in individuals knowing their risks and deciding how much privacy they're prepared to compromise. Under a National Science Foundation CAREER grant, Lee is developing "computational tools that enable everyday users to better manage their system participation by understanding the interplay between security, privacy, and utility." Besides benefiting the casual browser, such tools could enable employees to adjust privacy protections or tell a whistle-blower what information he or she could access without sending up red flags. Lee's 55 publications range in topic from location-sharing decisions to secure cloud transactions to policy.

Now in the vanguard of user-centered privacy, security, and distributed systems, Lee "had no idea what I wanted to do" on entering Cornell in 1999. He found the "right place" in computer science after a co-op at Sandia National Lab, and he went on to earn a Ph.D. in computer logic and theory from the University of Illinois, Urbana-Champaign. "I want to be the guy looking for problems and solving them," Lee recalls telling his Sandia mentor.

His computer-security interests segue smoothly to the classroom. A lesson in passwords, for instance, sends students to the dictionary to learn how eight-letter words limit users to too small a subset of possibilities. With the NSF grant, Lee is developing two undergraduate courses that explore social, technical, and privacy implications of digitized society. When it comes to his own interactions with technology, Lee limits his Facebook exposure and hates texting. "I'm terrible with keeping in touch," he says, laughing.

Amy Kaleita

SOIL WHISPERER


Image Courtesy of Amy Kaleita

From the air or highway, America's fruited plains present a uniform vista of vast abundance. Not to Amy Kaleita. The associate professor of agricultural and biosystems engineering at Iowa State University sees a "nonlinear, somewhat chaotic" array of microplots, each with unique hydrology, root depths, soil characteristics – and ripe opportunities for smart technology to enhance both sustainability and food production.

"Precision conservation," Kaleita's research field, piggybacks on the precision farming that GPS-equipped combines launched in the 1990s. Beyond optimizing crop yields, she seeks to "maximize the agricultural impact by treating the soil differently," applying data on erosion, fertilizer runoff, and other environmental factors to better manage land.

In her dream scenario, outlined in a 2013 Gilbreth Lecture at the National Academy of Engineering, temperature and water sensors in the soil would help customize seed depth; aerial drones and satellite imagery would monitor growth; and future plantings would be adjusted to cut chemical use. Faster, cheaper technologies – like tracking plant nutrients with a smartphone, a project of her Spatial Data Analysis Lab – can improve such time-tested techniques as crop rotation and pairing. The result: bigger harvests with a smaller enviromental impact.

Kaleita didn't grow up on a farm and hadn't heard of agricultural engineering until arriving at Penn State University interested in biomedical engineering but finding no major. Attracted by the chance to take microbiology as an elective, she "got hooked on the idea that food and the environment are just as fundamental as health care. That satisfied my desire to contribute to society" and led to a Ph.D. from the University of Illinois. Kaleita's own "big learning curve" in agriculture helped her become an award-winning teacher of conservation engineering and soil and water conservation management, "because I know how hard it is to learn something so foreign." In turn, her research – from climate change to assessment of agricultural engineering programs – benefits from her students' fresh perspective. "There's a highway of learning that runs both directions," says Kaleita. And it runs through fertile engineering ground.

Cary Pint
ENERGIZING BATTERIES

Image Courtesy of Cary Pint

Suppose that instead of hauling a 1,000-pound battery, an all-electric car could store energy throughout its hood, doors, roof, and fenders. Now imagine that rather than recharging every 250 miles or so, the vehicle got an extra jolt of energy every time it passed under a stoplight or through a toll booth. Cary Pint is working to make all this a reality. Embedding nano batteries and supercapacitors in advanced composite materials, the Vanderbilt University physicist turned engineer aims to transform energy storage – and not just for automobiles. With an extra step in manufacturing, he says, roof shingles and siding on a home could store energy from solar panels, providing power at night and on overcast days. A Boeing 747 could store enough energy in its fuselage to take off – currently the most fuel-guzzling period of a flight.

Pint, 32, an assistant professor of mechanical engineering and director of the Nanomaterials and Energy Devices Laboratory, sees the current state of grid-dependent energy storage and supply systems as a bottleneck, slowing down innovations in technologies requiring external power. His lab is working on batteries with 10 times the capacity of lithium-ion batteries and integrating batteries into a variety of materials to yield products – from robotic aircraft to buildings – that double as energy depots. "This area is both exciting and overwhelming because there are so many materials and technologies where energy storage can be integrated."

"A critical part of our research program" enlists undergraduates, often early in their studies, to work in the lab, Pint explains. "We throw them into an environment where they must be creative, to employ knowledge beyond that described in the literature. Some students love it. Some will struggle a lot." Much of learning, he says, is a process of acquiring technical language, which comes with lab experience. While Pint himself holds a Ph.D. in applied physics from Rice University, he enjoys making students realize "they don't need a fancy degree to innovate."

Jason Hayward
LOOSE NUKE DETECTOR

Image Courtesy of Jason Hayward

If one thing keeps top leaders awake at night, said former Defense Secretary Robert Gates, it's the thought of a terrorist with a weapon of mass destruction – "especially nuclear." Even before 9/11, Pentagon experts warned that the nation needed a better way to detect a nuclear dispersal device or improvised nuclear explosive. Official concern deepened years later when stocks of helium-3 – used in radiation detectors at ports and border entry points – ran dangerously low.

Enter Jason Hayward, 36, an associate professor of nuclear engineering at the University of Tennessee, Knoxville with a joint appointment at Oak Ridge National Laboratory. A veteran of the Navy with a Ph.D. from the University of Michigan, Hayward investigates new ways to detect radiation through advanced imaging and novel sensors.

He and his colleagues are pursuing several approaches. To pick up threats at long range, they're designing gamma ray and neutron imaging systems that for the first time pull together all available signals emitted by shielded fissile materials. Additionally, he leads a multidisciplinary, international team developing advanced sensors for a fast-neutron imaging technique that not only detects but also can determine the properties of bomb-grade uranium in shielded containers. A third project explores numerous types of glass as materials for efficient, low-cost sensors to detect fissile materials.

But the project with the biggest potential impact – "if we can make it work," Hayward says – exploits advances in optoelectronics to transform neutron imaging and yield a hundredfold improvement in resolution quality.

All the high-level worry about loose nukes has made Hayward one of the best-funded researchers of his generation. Since joining UTK and ORNL in 2008, he has brought in $9 million in grants, including $3.7 million from the Department of Homeland Security. Beyond screening cargo for nuclear contraband, his work has applications in verifying nuclear treaty compliance and in medical imaging – promoting health as well as safety.

Hayward, who came to enjoy teaching as a Navy instructor, mentors up-and-coming researchers – from undergraduates to postdocs – and reviews educational materials for the International Atomic Energy Agency. He also coordinates UTK's dual-degree program in science and engineering with historically black Fisk University.

Sujata Kumari Bhatia
RX FOR THE DEVELOPING WORLD

Image Courtesy of Sujata Kumari Bahatia

By the time she started teaching in her early 30s, Sujata Kumari Bhatia could claim a career's worth of achievements. After earning an M.D. and a Ph.D. in bioengineering, she spent eight years as a research scientist at DuPont, securing one patent and filing three more, writing or co-authoring five books and 80-plus articles and papers, and snagging dozens of academic and professional honors. But two years as an adjunct at the University of Delaware, her alma mater, steered her in a new direction. She ultimately accepted a non-tenure-track post at Harvard and the chance to coax a new generation of biomedical engineers to identify unmet societal needs.

Bhatia hadn't been at Harvard long before a Nigerian student sought her out as a senior project adviser, drawn by Bhatia's work in natural biomedical materials. The young woman's thesis examined potential medical applications of an array of materials common to developing countries. She and subsequent advisees persuaded Bhatia that "our youngest students can actually be our best innovators." As Bhatia explained to a TEDx audience: "They have heart. They have courage. They don't realize that anything is impossible, so everything is possible."

Inspired by her Nigerian student, Bhatia, now 36, has forged ties with researchers in Africa through Harvard's Belfer Center for Science and International Affairs and conducted workshops in Kenya, Nigeria, and Mauritius on low-cost medical solutions, including biopolymers derived from local materials like seaweed. As a lecturer and administrator in Harvard's biomedical engineering department, she keeps a hand in research – tissue regeneration is a keen interest – by advising undergraduate and graduate students.

"What I see when I talk to students is passion in two areas: sustainability and health care," Bhatia says. "They really want to fix problems." Her latest project will encourage the trend. With three siblings, all engineering educators, she's co-authoring a freshman engineering textbook. Its working title: *Empowered to Engineer.*

Laurel Riek
RESPONSIVE ROBOTS

Image Courtesy of Laurel Riek

Whether it was watching *Star Trek* episodes on Saturdays or devouring books on artificial intelligence while working at her local library, Laurel Riek knew at a young age that she wanted to build robots for a living. And what remarkable machines hers turned out to be. Riek, an assistant professor of computer science and engineering at the University of Notre Dame, makes robots that can respond to the human social world through realistic facial expressions and movement, and adapt to social cues. Her work is advancing the field of patient simulators, which are used by over 180,000 clinicians each year to learn how to respond to patient reactions.

Riek's girlhood passion took her first to Carnegie Mellon University, where she studied artificial intelligence on a scholarship, and then to a job as an AI engineer at MITRE, a research nonprofit. Over the next eight years, she worked on search-and-rescue robots, ground-based vehicles, and aerial vehicles. Eventually, she began writing proposals and acquired her own lab. "In retrospect, it was incredible to have access to those sorts of resources in my 20s," Riek says. She went on to earn a Ph.D. from Cambridge University under a Qualcomm computing fellowship, specializing in robots that interact with humans.

Now director of a robotics, health, and communications lab, Riek won an NSF CAREER award in 2013 for her work on simulations of human patients that can express pain, strokes, drowsiness, and other neurological impairments. Most simulators can already breathe, bleed, and respond to medications, Riek says. Her lab is taking that one step further and creating robots that can mimic signs of stroke, neurological impairment, and general pain using accurate facial expressions that are based on those of real patients. Just as humans can change their behavior depending on what others are doing, she says, "We'd like to enable robots to do the same thing."

Micah Stickel

TEACHING HOW TO LEARN

Image Courtesy of Micah Stickel

Micah Stickel vividly recalls the lab where, as an electrical engineering undergraduate, he suddenly saw how all those theoretical ideas from class "were actually being put into practice." Today, the University of Toronto senior lecturer pioneers high-tech and hands-on techniques to give every student such aha! moments from day one.

"I'm a facilitator of experiences, not a deliverer of content," explains Stickel, who shunned the tenure track for teaching when he joined the faculty in 2007 after earning a Ph.D. from Toronto. His innovations have been evolving since he was a TA. To motivate and help passive learners with often-conceptual material, he introduced clickers, online quizzes that targeted misconceptions, and activities that provide instant feedback in large lectures. "It's amazing how the class as a whole moves to the right answer," says Stickel, who sees correct response rates jump from 50 to 80 percent after students think and talk about the problem.

He was one of the first on the faculty of applied science and engineering to abandon the blackboard and teach entirely with a tablet PC and also spearheaded online core subjects, including calculus and mechanics.

Now honing the engineering school's first "flipped" class in a required second-year course on electric and magnetic fields, Stickel says the technique allows the introduction of "significantly more" engineering applications and current research but so far has failed to boost learning outcomes. "We're not quite there yet," he acknowledges. Only 60 percent of his students watched the online lectures before class. One promising sign: Many students in the inverted class found that they crammed less for exams.

Winner of one faculty and four departmental teaching awards, Stickel was named chair of first-year programs in 2012 and led a review of the first-year curriculum and delivery. His big concern is how little students "take with them," a problem he witnessed teaching second-year physics. That's why his ultimate goal is to use technology intelligently to teach students how to learn, so they can carry concepts forward to the next year.

Blanka Sharma

CELL BUILDER

Photo by Ray Carson – UF Photography

Blanka Sharma joined the Cleveland Clinic as a postdoctoral fellow in 2009 just as nanotechnology and gene therapy combined to break promising new ground in cancer treatment. Soon she became a major contributor to the growing field. Zeroing in on the tumor-suppressing p53 gene, which mutates and goes awry in half of cancer patients, she and her colleagues demonstrated how polymeric nanoparticles containing this gene in its healthy form could be successfully injected into tumors and suppress prostate cancer in mice.

Now an assistant professor at the University of Florida, Sharma, 35, is breaking the mold of new faculty – an entrepreneur who went from academia to industry to start-up, and from energy to the intersection of engineering and medicine. Gaining attention for materials that not only fight cancer but also regenerate tissue, she's one of about 100 scientists and engineers picked for a National Academies Keck Futures Initiative conference in November entitled "Collective Behavior: From Cells to Societies."

After earning a chemical engineering degree from Canada's University of Waterloo, Sharma worked briefly in the oil and gas industry before entering a doctoral program in biomedical engineering at Johns Hopkins University. "As a chemical engineering undergraduate, I didn't get a lot of exposure to biomedical," she says. "I think I wanted something more altruistic – at the end of the day, I wanted to help people." With three other graduate students, she developed a prize-winning business plan for an imaginary company that could help doctors detect eye diseases before they cause blindness.

Becoming fascinated by tissue engineering via stem cells, Sharma joined a Hopkins lab that designed and formulated hydrogels to make stem cells grow into cartilage. When her adviser and an orthopedic surgeon used the results to create a start-up, Cartilix, she became its director of research. After Cartilix was bought out in 2009, she joined the Cleveland Clinic, witnessing research from "bench to bedside."

With her wide experience, it's a cinch she'll be a sought-after mentor at Florida.

Stephanie Luster-Teasley

'LAB RAT' WITH A PASSION FOR DIVERSITY

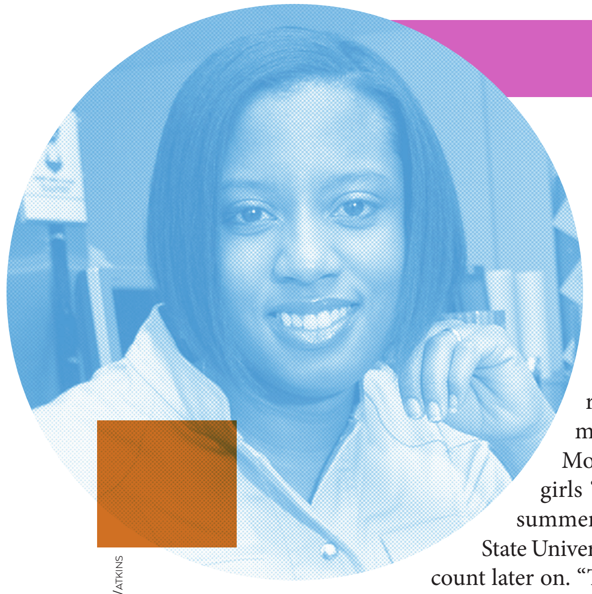

Image Courtesy of Charles E. Watkins

They fill and dispense fluid from pipettes, perform college-level analyses of bacteria, and tie-dye lab coats using markers and isopropyl alcohol. Mostly, though, middle school girls "really bond" in a week long summer lab at North Carolina A&T State University. Their fond memories will count later on. "They're going to be superstars in math and science," predicts the program's founder, Stephanie Luster-Teasley. "If they get frustrated, they can think back and say, 'I had fun.'"

A self-described "lab rat" whose work in chemical oxidation and remediating wastewater has netted several National Science Foundation grants, Luster-Teasley is having an equal impact as an educator. Her Girls in Science Lab initiative, aimed at showing young African-American women that college is attainable, is one of several that won Luster-Teasley ASEE's 2014 DuPont Minorities in Engineering Award.

In 2010, she developed hands-on experiments to teach 4-H youngsters about global warming that have since gone viral, teaching millions of kids worldwide about the buildup of carbon dioxide in the atmosphere by putting Alka-Seltzer in a paper bag. More recently, she launched the Engage 2BE program, which provides mentoring, stipends, academic support, and professional development to North Carolina A&T students interested in bio- and environmental-engineering careers.

Luster-Teasley, an associate professor of chemical, civil, environmental, and biological engineering, pushes her university students to enter co-op programs and attend conferences. "It's really important to get kids out of their seats," she says. Having worked in industry after earning a Ph.D. in environmental engineering at Michigan State, she laces her lectures with case studies and examples from her former professional practice, like finding dead beavers after their pond had been remediated. Equally credible is her admonition to students "to work on your writing" because, she tells them, "80 percent of what I did as a consultant was writing papers." Her latest helpful and practical project: using social media to alert students to grants, internships, and other opportunities to help them start earlier and submit stronger applications.

Jim Pfaendtner

SUCCESS COACH

Image Courtesy of Jim Pfaendtner

"Women, listen up," Jim Pfaendtner commands, commencing his senior chemical engineering class at the University of Washington by outlining his students' next career steps. Laying out the stubborn gender gap in pay for identical degrees, the assistant professor offers to help negotiate salaries or navigate a job fair. The coaching is open to all students, but Pfaendtner wants women and underrepresented minorities to know he means it. So far, he has mentored all who asked.

As career counselor, award-winning teacher, and adviser to first-generation college students and campus organizations, Pfaendtner wins accolades from students and faculty alike. His course evaluations are literally off the charts, topping 5 on a 5-point scale. Chemical engineering student Kathryn Cogert calls him "a force of nature." Peers praise such innovations as the way he transformed senior-level courses by linking their content and flipping the classroom. The NSF-funded biofuels-production lab he helped develop lets students for the first time evaluate the effects of decisions up and downstream.

He seems to possess the bandwidth to succeed in research as well as the classroom, having won an NSF CAREER award – from two divisions – funding his lab's use of state-of-the-art computational tools to improve the efficiency of enzymes in converting crops to fuel. But the educational component is never absent. While his doctoral students publish in top journals, Pfaendtner started a book club to encourage "ownership over their careers." His must-read: *A Ph.D. Is Not Enough.*

He also opens the lab to undergraduates through the Louis Stokes Alliance for Minority Participation. "The thing that's just burning inside of me is using my position of influence and authority to improve people's lives," explains Pfaendtner. Besides, he notes, "we graduate 65 newly minted chemical engineers a year and we owe it to society to train them well."

"A terrible chemistry student" in high school, Pfaendtner discovered his own talent and awakened to the subject during a summer program at Georgia Tech. He enrolled there, "fell in love" with chemical engineering, and now calls himself "a cheerleader" for the discipline.

Raffaella De Vita

MOTHER OF INVENTION

Image Courtesy of Raffaella De Vita

Eureka moments can strike in odd places. Raffaella De Vita, a soft-tissue expert and associate professor of engineering science and mechanics at Virginia Tech, discovered her niche at the forefront of reproductive health while seven month's pregnant with her second child. She was crossing campus, pondering how to craft a ligament-research proposal "novel" enough to pass NSF muster, when she felt pain on both sides of her abdomen. "That's interesting," she thought, and hit Google for possible causes.

Nothing turned up. Even the names and anatomical descriptions of ligaments supporting the uterus and vagina varied widely. "It was really a mess!" recalls De Vita. That seemed surprising given that incontinence, pelvic-organ prolapses, and other disorders affect a third of female U.S. adults. Startling, too, was the lack of scientific research guiding surgery – costing Americans $1 billion annually – to treat such conditions.

De Vita suddenly saw where her work could make a difference. Weeks after giving birth, she refined and submitted a winning NSF CAREER proposal to study the elastic and viscoelastic properties of two major ligaments supporting the uterus and the vagina. The following year, 2013, she won a Presidential Early Career Award for Scientists and Engineers (PECASE).

"Having a baby really inspired this research," says De Vita, who never imagined as the daughter of an Olivetti worker in Italy that her career trajectory would include a Ph.D. in mechanical engineering from the University of Pittsburgh and meeting a U.S. President.

Since struggling to find her initial collaborator, an Army gynecologist and researcher, DaVita has seen growing interest in her field, with the world conference of biomechanics holding sessions on female reproductive mechanics. Meanwhile, her email is flooded with requests for guidance on disorders that many women were, until recently, too embarrassed to discuss. Not so her kids, 3 and 8, by now accustomed to clinical talk laced with words like "vagina."

Carl Nelson

HEALING INGENUITY

Image Courtesy of NASA

After barely surviving a car crash, a 16-year-old girl entered rehabilitation several years ago still brain damaged, her movements uncoordinated and her leg muscles atrophied. Yet when Carl Nelson saw her earlier this year, she was walking normally and "looking great," thanks in part to the sensor-equipped Intelligently Controlled Assistive Rehabilitation Elliptical (ICARE) exercise machine that he developed with therapists at Madonna Rehabilitation Hospital in Lincoln, Neb. Based on the kind of elliptical trainers found in gyms, the $30,000 treadmill-size device offers many of the same benefits to stroke and brain-injured patients as rehabilitation machines that take up 35 square feet and cost 10 times as much.

Refining medical technology to cut costs and make it easy to use is a hallmark of Nelson's research at the University of Nebraska, Lincoln, where he is an associate professor of mechanical and materials engineering. "If I'm doing a good job, it solves the problem with the least complexity," he says. A recent example is a walker designed to keep users from falling. Wheeled walkers offer good mobility but can slide out of control if an individual loses balance, hastening a fall. Nelson, with the help of several undergraduates, fashioned a passive brake mechanism – inspired by a retractable ballpoint pen – that halts the walker when the user applies downward pressure on the handlebar.

Nelson's "keep it simple" approach extends to tools for advanced minimally invasive surgery, including the state-of-the-art, no-incision Natural Orifice Translumenal Endoscopic Surgery (NOTES). A complication with this kind of robotic surgery comes when the surgeon needs to change instruments. Existing equipment, powered by electric motors, is bulky and slow. With a surgeon at the University of Nebraska Medical Center, Nelson developed a hydraulic manipulator, which works much faster and is half the size of the electric version.

With his hectic research pace, Nelson teaches fewer classes than some of his colleagues but seems to do more than his share of mentoring, including guiding projects of several students in the McNair Scholars undergraduate research program.

Rodney Priestley

PRINCE OF POLYMERS

Image Courtesy of Rodney Priestley

Rodney Priestley says his Princeton polymer lab may be just a few years away from cracking one of the big mysteries in nanotechnology. At the nanoscale, the properties of materials change markedly in various ways, such as electrical conductivity. Working with glassy polymers, Priestley and his colleagues are gaining the potential to control and "tune" these alterations in behavior. But "*why* these changes occur at the nanoscale is still the basic question," Priestley says. Once engineers understand the why, they'll be better able to manipulate the properties and maintain a material's mechanical integrity – a leap toward exploiting this phenomenon in developing new technology.

Priestley, an assistant professor of chemical and biological engineering, became fascinated by polymers while taking Organic Chemistry II and Polymer Physics at Texas Tech University, where he also performed well at the long jump. His interest deepened when he helped develop artificial bone material from polymers at a University of Connecticut lab under the federally supported Research Experiences for Undergraduates program. He went on to earn a Ph.D. in chemical engineering from Northwestern and spent a postdoctoral year at ESPCI ParisTech, a French science and engineering school, before being hired by Princeton in 2009. Since then, Priestley has secured a National Science Foundation CAREER grant, a coveted President's Early Career Award for Scientists and Engineers (PECASE), and an invitation to the 2014 National Academy of Engineering's Frontiers of Engineering Symposium in 2014.

Laser-focused on fulfilling the tenure track's research demands, he nonetheless cofounded a start-up, Sphera Materials, which commercializes such breakthroughs as the "low-energy, one-step, and continuous" production of certain nanoparticles demanded by industry. He's also an adviser to Princeton's Wesley L. Harris Scientific Society, an organization of underrepresented minority graduate students in science and engineering. He counsels students to first strive for excellence in their own scholarship, and secondly to promote diversity in science, creating a community of minority scholars on campus.

SOLOMON DIAMOND

CREATIVITY FIRST

Image Courtesy of Solomon Diamond

"Riders, are you ready?" asks Solomon Diamond as students prepare to race around Dartmouth's sunny lawn in whimsical di-wheel vehicles they created in his advanced computer-aided mechanical engineering design course. With an affirmative roar, the drivers begin pedaling and hand-cranking through a four-lap contest that constitutes their final project. "It's easier to stimulate creativity and the ability to invent in a space that's carefree," explains the associate professor of engineering, whose own creative endeavors include advanced neuroimaging technologies.

That teaching philosophy reflects a lifelong zest for invention. Growing up in rural Bath, N.H., where his family operated an industrial-scale hydroelectric generator and a computer business, Diamond crafted rubber-band dart guns, assembled PC clones, and learned to repair heavy equipment. In eighth grade, the self-taught database expert set up inventory-tracking systems for local businesses.

As a Dartmouth engineering major, Diamond worked with a local entrepreneur on a water-jet device that potentially could break up kidney stones. That launched him on the biomedical technology path. A senior capstone project with the same mentor resulted in an exercise machine for elderly, bedridden hospital patients – and two U.S. patents. He went on to earn a top teaching award from Harvard while paying for grad school with a neuroimaging grant that combined brain functioning and disorders.

Joining Dartmouth's faculty in 2008, Diamond took hands-on learning to new levels. "I don't want [students] to be designing for a grade," he says. "I want them to be designing for their own internal passion." Meanwhile, Diamond's multimodal neuroimaging lab is pioneering technologies to improve diagnosis and treatment of brain disorders. One project, funded by the National Institutes of Health, combines EEGs with near-infrared spectroscopy and fMRI imaging to study the connection between neural action and blood dynamics, a potential key to understanding multiple sclerosis.

To balance research and teaching, Diamond has "learned to be efficient in the classroom" – and expand the teaching space. He invites students home to dine and conduct energy audits at his super-insulated, net-zero house. "One of the great things about teaching is you get to share some of your life with students and vice versa."

Jose Palacios

DEEP CHILL SPECIALIST

Image Courtesy of Jose Palacios

As a 17-year-old gymnast competing on Spain's national team, Jose Palacios saw too many fellow athletes retire due to injury or age and not have a backup career plan. So he sought and won an athletic scholarship to attend Penn State University, where he helped the school's Division I team win NCAA championships in 2000 and was voted Most Valuable Player that same year. As team captain in 2003, he led the team to win the Big 10.

Palacios spoke almost no English when he first came to the U.S. "One of the reasons I became interested in engineering was because math is its own language," he says. Of choosing to pursue aerospace engineering, he jokes: "At the time, I was happy I could understand the word 'aerospace' in both English and Spanish." Making the dean's list every semester, he went on to earn a master's in aerospace from Penn State. For his Ph.D., he designed a room that can test how well 10-foot helicopter rotors hold up while spinning in a freezing chamber that sprays clouds of ice.

Joining Penn State's faculty in 2013 after five years as a postdoc, Palacios teaches introductory and advanced aerospace structures while designing never-before-seen experimental facilities to study how wind turbines, aircraft, and engines behave under extreme freezing conditions. One is an icing wind tunnel that compares freezing conditions under different types of air flow. He and his lab colleagues draw funding from NASA, General Electric, the National Rotorcraft Technology Center, and the Army Vertical Lift Research Center of Excellence based at Penn State. "Dreaming up a system, putting it together with your hands, to then have a needed working product is extremely enjoyable," Palacios says, "especially when the design pushes the limit of what is possible with available resources." When he sees "the hunger in other students for getting their hands on experiments," he can tell they're experiencing the same thrill.

Image Courtesy of Helen Hsu-Kim

Heileen Hsu-Kim

POLLUTION SLEUTH

Heileen (Helen) Hsu-Kim approaches a huge problem – water pollution – along the narrowest of pathways. An expert on toxic metals and chemicals in the natural environment, the Duke University associate professor of civil and environmental engineering investigates how mercury, arsenic, and selenium behave at the molecular level. She discovered, for instance, how tuna and swordfish could absorb more mercury than freshwater catfish, despite a lower concentration of mercury in seawater. (It binds with the salt and lasts longer.) She and her team found previously overlooked ways that strip-mining and combustion of coal can foul streams, sediment, groundwater, and fish habitats. And they traced poisonous methylmercury in two Tennessee rivers to a 2008 coal ash spill, something the U.S. Environmental Protection Agency had missed.

Growing up in Pittsburgh as the daughter of two Taiwan-born immigrants trained in the medical profession, Hsu-Kim "always liked applying science to solve problems." She veered away from biology on finding she was "not very good at growing things in a lab" and turned to aquatic chemistry and environmental engineering as an MIT undergrad. Now a recognized leader in a field called nanogeochemistry, she earned an Early Career Research Award from the Department of Energy and a 2012 President's Early Career Award for Scientists and Engineers (PECASE). "Ultimately, we want to identify how pollutant metals behave in the environment, predict their impacts, and find ways to reduce their toxicity," Hsu-Kim says. Reaching beyond toxic metals, her research lab is now examining the environmental impact of nanomaterials and extracting rare earth elements from coal ash. Its collaborations stretch as far as Peru's Madre de Dios region; research on water sustainability includes colleagues in France, Turkey, and Singapore.

Having survived lean years as a poorly funded young researcher, Hsu-Kim passes on lessons learned about sharing students with other labs, leveraging equipment, proposal writing, and getting peer feedback. She also relishes working one-on-one with graduate and undergraduate students, whom she wants to become intellectually independent critical thinkers and leaders. Mentoring, in fact, "is the best part of the job."

Jeff Rhoads

FASTER CHIPS, SMARTER CLASSROOMS

Image Courtesy of Jeff Rhoads

For years, the semiconductor industry has wondered when it would reach the limits of the 1965 observation by Intel co-founder Gordon Moore that computer chip performance doubles approximately every other year. But Purdue University mechanical engineer Jeff Rhoads and his colleagues think they're on the way to "circumventing Moore's law," as Rhoads puts it. Rather than shrinking traditional transistors to squeeze more on a chip, they're boosting processor speed by affixing chips with nanoelectromagnetic systems (NEMS), the remarkable sensors that operate with microwave frequencies and can respond in nanoseconds. With a $360,000 National Science Foundation grant, Rhoads aims to model, design, and put together nanosystems that can be integrated with chip technology. The challenge is making the somewhat unpredictable NEMS compatible with chip manufacturers so these tiny devices can be mass-produced.

Past research into NEMS and their larger cousins, microelectromagnetic systems, has laid down a strong foundation of science, Rhoads says. "We're really trying to take things that were explored 10 years ago and turn them into practical devices." His reconfigured chip is just "the tip of the iceberg" of potential breakthroughs in the field.

As he tries to scale up NEMS-powered chips, Rhoads likewise wants to expand the toolbox of effective teaching techniques to cope with rising enrollments and improve retention. Unsatisfied by his own high ratings from students – "I always got the sense that students appreciated it if they saw you trying and you were accessible" – he tries a variety of approaches to seize on the multiple ways students learn. YouTube can be powerful, he says, particularly if it reveals how an expert approaches a problem. It's one of the methods – along with interactive blogs, "lecturebooks" combining texts and lecture notes, homework collaboration, and traditional lectures – that he and three colleagues have packed into their Mechanics Freeform Classroom. Based on student gains so far, Rhoads thinks it marries the best of massive online open courses (MOOCs) with Purdue's traditional "hominess" and could go global. Still just 33, he's thinking big.

Shawn Jordan

DIY ENGINEERING

Image Courtesy of Shawn Jordan

As a Purdue graduate student in 2005, Shawn Jordan co-led his team to victory in a Rube Goldberg contest – and snagged a Guinness world record – with a machine that took 125 steps to turn on a flashlight. The following year, his team won again, this time with a contraption that "ate my homework" in 215 steps, including a player-piano rendition of the school's fight song.

To Jordan, the exercise of turning simple tasks into complex contortions takes creative engineering to its limit, spurring students to "design the problem as well as the solution." Thus it's an ideal teaching tool. He introduced Rube Goldberg to high school students while pursuing an engineering education doctorate. Now, as an assistant professor of engineering at Arizona State's College of Technology, he is using it in a project to develop a next-generation science and engineering curriculum for Navajo middle school classrooms. In the process of designing and building the machines, students produce stories about their culture and daily lives. He also incorporates Rube Goldberg ideas in STEAMLabs, a rapidly growing series of clubs that combine engineering design and art.

Jordan's approach, which merges social science and engineering, has struck a responsive chord with funding agencies eager to identify successful STEM teaching techniques. Since 2011, he has obtained $1.9 million for his research, including a National Science Foundation CAREER award. Currently, NSF is backing his study of the community of "makers," whose inventions draw crowds to Maker Faires around the country, to learn what compels them to tinker and innovate. The resulting evidence, he argues in an abstract, "will transform the conversation of who young makers could become, linking making with engineering in the same way that students who excel in science and math are pointed toward engineering by parents and career counselors."

The project appeals to his interest in the human side of engineering. "I was always drawn toward psychology," he says. "Engineering education brought together my interests in people with my interests in engineering."