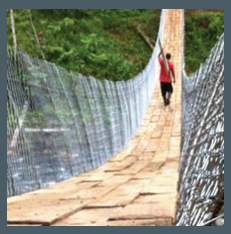

FINDING THEIR PASSION

Dissolving the classroom borders

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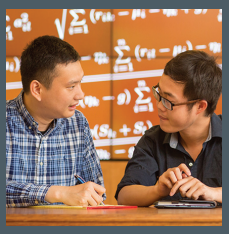

DIGITAL GATEKEEPING

Stressing security in a virtual world

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A FOCUS ON LEHIGH ENGINEERING • VOLUME 1, 2018

THE SKY IS THE LIMIT

INTERDISCIPLINARY TEAM SCIENCE RISES IN NEW HUB FOR DATA AND COMPUTATIONAL INNOVATION

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LEHIGH UNIVERSITY | P.C. ROSSIN COLLEGE OF ENGINEERING AND APPLIED SCIENCE

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LEHIGH UNIVERSITY

Leading through research

Welcome to the Spring 2018 issue of* Resolve*—a magazine dedicated to research and educational innovation in the P.C. Rossin College of Engineering and Applied Science at Lehigh University.

In this issue of our magazine, we share exciting news of transformational activities taking shape in and around the Rossin College. These activities center around the College's top strategic priorities—interdisciplinary research and experiential learning—both of which bring together teams of our faculty members, students, and partners to address challenging research problems and to provide productive learning environments.

Based on results of the College's faculty-led Envisioning Process, Lehigh is poised to launch three new Interdisciplinary Research Institutes (IRIs) that will enable the University to solidify and further develop its strengths in key areas, and to lead on the national and international stage.

Interdisciplinary team science is essential to the solutions of society's most pressing challenges, and Lehigh's IRIs are designed to help lead the way. The University's inaugural Institutes are focused on functional materials and devices; data, intelligent systems, and computation; and cyber–physical infrastructure and energy.

These Institutes will enhance Lehigh's culture of interdisciplinary excellence, and build upon this culture to incubate and catalyze teams of scholars that pursue fundamental and applied research in areas of broad societal importance. As beacons of this scholarly excellence to the world, the Institutes will communicate and promote Lehigh's research productivity, impact, and reputation in these critical domains.

The cover feature (p. 16) focuses on work underway around the new Institute for Data, Intelligent Systems, and Computation. Work in this Institute revolves around the study of problems that involve massive amounts of data and/or large-scale computations, and developing the science that enables the extraction of useful and actionable information across disciplines and research fields. This Institute is an expression of Lehigh's emerging strength and commitment in this interdisciplinary field of study and exploration, as well as a model for our future as a research and educational enterprise.

The Institute will be housed in the unpretentiously-named Building C on Lehigh's expanding Mountaintop Campus. Over the past five years, a "revolutionary overhaul" of the building has taken place, transforming the colossal, midcentury structure into a hub of interdisciplinary research and experiential learning. The building is also home to Lehigh's innovative Mountaintop Initiative, as described on Page 22 in our interview with Khanjan Mehta, Lehigh's inaugural Vice Provost of Creative Inquiry and Director for the Mountaintop Initiative.

"These Institutes will incubate and catalyze teams of scholars that pursue fundamental and applied research in areas of broad societal importance."

The interdisciplinary Mountaintop team projects are just one component of our strategic focus on experiential learning, which is explained in detail on page 10. The experiential learning opportunities available to our students enable them to find their passion and connect more deeply with their chosen fields of study. Note that the inside back cover highlights Team Soterra, one of the exciting projects that we are supporting through our Experiential Learning Fund.

Core facilities that house state-of-the-art equipment are essential enablers of our cutting-edge research and educational programs. In this issue, we highlight the outstanding success of all three Lehigh teams awarded grants from the intensely competitive annual Major Research Instrumentation (MRI) program of the National Science Foundation (p.14.) The resulting equipment will find their homes in our Materials Characterization and our Nanofabrication Facilities.

Especially during this exciting time of growth and transformation, thank you for your interest in Lehigh engineering and the Rossin College! Please drop me a line with your thoughts and comments.

Stephen P. DeWeerth, *Professor and Dean*
P.C. Rossin College of
Engineering and Applied Science
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A cool, clean legacy

Lehigh water filtration tech builds momentum through socially conscious entrepreneurship

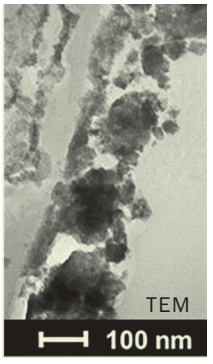
Across more than three decades as a professor and leading researcher at Lehigh University, Professor Arup SenGupta has mentored a veritable army of young innovators in the development of solutions that holistically address the problem of groundwater contamination. They create sustainable water technologies around the globe, both in developing and developed countries.

The World Health Organization calls the arsenic crisis "the biggest mass poisoning in human history" and Human Rights Watch believes some 20 million people are at risk from arsenic poisoning in Bangladesh alone, according to a BBC news report.

The basis of the firm's technology—a water filtration nanotechnology resin called Hybrid Ion Exchange Nanotechnology (HIX-Nano)—was developed by SenGupta's research team. The zirconium-based resin removes arsenic from the water, which is then filtered through a series of Drinkwell tanks that remove additional harmful substances. In recent years, SenGupta and his students have extended their technology's original arsenic-busting powers to attack other contaminants, namely fluoride, phosphate, and lead.

PHOTO COURTESY ARUP SENGUPTA

(Above) Schoolchildren in the Birbhum District in West Bengal, India, wait in line for fresh drinking water filtered by the HIX nano system.



(Below) Closeup views of a HIX nano resin bead slice with zirconium oxide nanoparticles.

20 MILLION

PEOPLE ARE AT RISK FROM ARSENIC POISONING IN BANGLADESH ALONE

Source: BBC

In July 2012, three Fulbright alumni—SenGupta, Minhaj Chowdhury and Mike German '17 Ph.D.—conceived and launched Drinkwell, an innovative start-up, in Lehigh's STEPS building. Their goal was to bring the University's water technologies to affected places around the world. Since then, Drinkwell has blossomed, and recently captured attention and support from a variety of organizations around the world including the BBC, *Forbes* magazine and Dell, Inc.

The firm establishes locally-maintained arsenic decontamination systems across India, Laos and Cambodia. Its technology provides villages with water filtration technology and tools to improve community health while generating income and creating jobs.

According to SenGupta, a professor in Civil and Environmental Engineering as well as Chemical and Biomolecular Engineering, at least ten Lehigh graduate students over the years have contributed toward Drinkwell's present status. From 2000 to 2010, confronted with the rising arsenic poisoning of millions caused by contaminated groundwater primarily in countries in the South and Southeast Asia including Bangladesh, Nepal, India, Cambodia and Laos, several of SenGupta's doctoral students, John Greenleaf '07 Ph.D., Prakhar Prakash '04 Ph.D., Prasun Chatterjee '11 Ph.D, Surapol Padungthon '13 Ph.D. and post-doc Sudipta Sarkar became intimately involved in mitigating the crisis.

SenGupta's current doctoral students, Jinze Li, Chelsey Shepsko and Hang Dong are conducting research to develop appropriate wastewater reuse technologies for California and China, as well as Marcellus wastewater treatment in Pennsylvania. Over the years, inventions resulting from the works of doctoral students have led to eleven U.S. Patents; several of these inventions are in use in different countries, including the United States.

The team's efforts haven't gone unnoticed. During the *Forbes* Under 30 Summit, Drinkwell co-founder Minhaj Chowdhury won the magazine's first-ever Under 30 Impact Challenge, taking in $500,000 for Drinkwell to continue providing services in India and Bangladesh. At UC Berkeley's 2015 Global Social Venture Competition, Mike German '17 Ph.D. won first prize among many competing technology start-ups for his project proposal, "Transforming Arsenic and Fluoride Water Crisis into an Economic Opportunity through Hybrid Ion Exchange Nanotechnology."

"The use of HIX-Nano has transformed the global arsenic and fluoride crisis into an economic opportunity for those suffering from it," says SenGupta, "while providing safe drinking water to thousands of people."

Kudos for corrections system optimization

Novel software leverages operations research for prison population management

RESEARCH RECOGNITION

A first-of-its-kind optimization model developed by Lehigh engineers—in collaboration with Pennsylvania's Department of Corrections (PADOC)—has received the prestigious Daniel H. Wagner Prize for Excellence in Operations Research Practice for 2017.

The Inmate Assignment Decision Support System (IADSS), invented by students and faculty members of industrial and systems engineering, streamlines the assignment of inmates to Pennsylvania's 25 correctional institutions and has been credited with saving the state millions of dollars.

IADSS can make hundreds of inmate assignments in a few minutes, a task that requires days when performed manually by humans. The system is the product of five years of work by graduate students and faculty members, including Tamás Terlaky, Louis Plebani and George Wilson, all faculty members in industrial and systems engineering, as well as Ph.D. candidate Mohammad Shahabsafa, graduate student Anshul Sharma, Dan Li '13 Ph.D. and Chatainya Gudapati '17G.

PADOC officials say the IADSS has "transformed" the inmate assignment process in Pennsylvania and can do the same for state correctional agencies across the United States. In the long run, they say, the system could shorten prison stays and reduce recidivism by giving inmates more timely access to the treatment programs they need to earn parole.

There are currently 46,800 inmates in the state's correctional institutions. PADOC's annual expenditures total approximately $2.5 billion, or about 8 percent of the state's total budget.

The Lehigh team says that IADSS represents the first application of operations research to the assignment of prison inmates.

In a report released Sept. 1, PADOC officials said IADSS has enabled the corrections department to achieve cost savings and improvements in four areas:

- Shorter waiting lists for treatment programs, which will reduce the length of time inmates remain in prison past their minimum sentence date;
- Fewer prison assaults through improvement in assigning the right combination of inmates to the right prisons;
- Fewer staff members needed to oversee inmate assignments and transfers; and,
- A reduction in the need for transfers of inmates among prisons.

"Based on these four criteria," the report said, "we believe that the IADSS has saved the PADOC, and thus saved Pennsylvania taxpayers, approximately $2.9 million during the first year, which will translate into approximately $19.2 million in savings over the next five years."

The Wagner Prize is awarded by INFORMS (the Institute for Operations Research and the Management Sciences), the world's premier professional association for analytics and operations research, and recognizes the application of "strong mathematics…to practical problems supported by clear and intelligible writing, the quality and coherence of analysis, [and] good writing, strong analytical content and verifiable practice successes."

Terlaky, along with fellow editors Miguel F. Anjos of Polytechnique Montréal and Shabbir Ahmed of Georgia Institute of Technology, has also recently released a new textbook to "provide a solid foundation for engineers and mathematical optimizers alike who want to understand the importance of optimization methods to engineering, and the capabilities of these methods." *Advances and Trends in Optimization with Engineering Applications*, as published by the Mathematical Optimization Society (MOS) and the Society for Industrial and Applied Mathematics (SIAM) is volume 24 of a prestigious MOS-SIAM series on optimization. Topics covered by the series explore the theory and practice of optimization, discussing algorithms, software, computational practice, applications, and the links among these subjects.

Coulter joins ASEE research board

John P. Coulter, Professor and Senior Associate Dean for Research, has been named to a prestigious position with the American Society for Engineering Education (ASEE), joining the board of directors of its Engineering Research Council (ERC).

The ERC is composed of representatives from engineering colleges, industry, and government. The council discusses issues and exchanges information pertaining to the research activities of ASEE society members.

"My role with the ERC enables Lehigh to keep current with the latest engineering research trends and best practices," says Coulter. "It also gives Lehigh exposure and influence on a national stage."

Coulter oversees the operation and continuous enhancement of engineering graduate programs and research throughout Lehigh University. He has served as co-chair of the university's strategic task force that developed its current vision and implementation plan for enhancing Lehigh's graduate studies and research. He was appointed interim dean of Rossin College in 2004 and again in 2015.

Coulter is a professor of mechanical engineering and mechanics and has nearly 30 years of teaching and research experience at Lehigh. His research focuses on manufacturing science and intelligent mechanical and material systems. He has led projects with faculty in all of the Rossin College's eight engineering departments and across the university, generated more than $9 million in research and teaching grants, has written more than 185 professional papers and holds several patents.

‘Eagle-eyed’ professor monitors deep learning security

Building a better brain, bit by bit

Autonomous vehicles, facial recognition, disease diagnosis—machines are increasingly being tasked with completing extremely complex, traditionally human tasks. And if it were a competition, humans are often firmly in second place.

“It was reported recently that deep learning systems can achieve better accuracy in identifying skin cancer than a human dermatologist can,” says Ting Wang, an assistant professor of computer science and engineering.

It wasn’t always this way. Research into deep learning systems and neural networks began in the 1970s when members of the artificial intelligence community said they wanted to develop something to simulate the human brain.

“The basic unit of the brain is the neuron. By connecting a bunch of neurons, they envisioned that they could simulate some functions of the human brain,” Wang says.

The maximum computing power of the era critically inhibited any serious attempt to mimic complex brain activity back then, but the overarching philosophy never went away. At that time, Wang says, engineers could only compute for two layers of activity and maybe a dozen neurons.

Jump forward a few decades to the early 2000s, and Wang says advances in computing infrastructure systems, including the advent of cloud computing, revived the idea.

“Now, we can build very large scale neural networks with hundreds of layers and millions of neurons,” he says, “and suddenly, because of the increase in the complexity of this architecture, and the amazing amount of data we have right now, we can do much more complicated things.”

However, for every deep learning success story, there’s a vulnerability.

Adversarial inputs are manipulations to the system that are imperceptible to humans. One example, Wang says, might be with image recognition software related to autonomous vehicles. An attacker might simply flip a few pixels of an image, so that the system recognizes it as saying “6 MPH” rather than “STOP.” If undetected, the result can be a traffic accident, which is why Wang says it’s critical that adversarial inputs are detected as such as quickly as possible.

That’s where his “Eagle Eye” comes in. It’s the name he gave to a research project funded by the National Science Foundation (NSF) to the tune of nearly $500,000. “The manipulation introduced to deep learning systems is so small a human eye cannot see it,” he says of the nickname. “That’s why we need an eagle eye—to identify these tiny pieces of adversarial inputs for what they are.”

Most attack defense and detection methods are static, which means when you deploy them, they just sit there, and the adversary eventually finds a way to circumvent them, Wang says.

That’s why his project was designed to detect adversarial inputs in an attack-agnostic manner. “It’s adaptive to the attacks,” Wang says. “They might be attacks we are unfamiliar with, but if they follow certain patterns, we’ll be able to detect them.”

Notably, this new method of detection is independent of the system itself, meaning you can build on it as you learn more about various attacks. You can also change it or improve it to fit the specific needs of your deep learning system, Wang says. Additionally, this independence means the presence of the detection and defense mechanism isn’t a drag on overall system performance.

When completed, the base product will be available to organizations and governmental agencies to use and build upon, and because it’s NSF-funded, Wang says it will be free to the public.

“A manipulation introduced can be so tiny that it is indiscernible to human eyes, but at the same time it can be effective enough to deceive the deep learning system,” says Wang (inset above, and with Ph.D. student Xinyang Zhang, right). “That’s why we need an ‘Eagle Eye’ to identify these tiny pieces of adversarial input for what they are.”

Reshaping engineering with an 'entrepreneurial mindset'

Lehigh-KEEN initiative wins kudos for educational innovation

Lehigh University's partnership with the Kern Entrepreneurial Engineering Network (KEEN) has won the 2017 Award of Excellence in the Innovation Category from the University Economic Development Association (UEDA).

UEDA's Awards of Excellence Program recognizes organizations who are transforming their campuses into engines of economic prosperity through leading edge initiatives. Projects were judged on scalability, sustainability, impact originality and replicability.

Lehigh's winning project is the Lehigh-KEEN Initiative. Lehigh became a KEEN partner in 2015, enabling the university to collaborate with 31 other partner institutions focused on elevating engineering education by incorporating core principles of entrepreneurial minded learning (EML).

Sue Perry is incorporating KEEN principles into Lehigh's bioengineering program.

"IF WE CAN USE ACTIVE, PROJECT-BASED LEARNING TO CREATE CONNECTIONS, WE WILL CREATE A GREATER DEPTH OF UNDERSTANDING FROM START TO FINISH IN THE CURRICULUM."

—Sue Perry

The Lehigh-KEEN Initiative is a comprehensive, multi-phased process designed to revolutionize engineering education by integrating EML and engineering skillset development within Lehigh's engineering education ecosystem.

KEEN, an initiative of The Kern Family Foundation, is a collaboration of colleges and universities dedicated to developing an entrepreneurial mindset in engineering students. The root of the entrepreneurial mindset that KEEN seeks to instill in engineers is summed up by KEEN's "3C's," curiosity, connections and creating value.

The idea is to encourage engineers to adopt holistic thinking that challenges conventional ideas and integrates fresh ones. By taking ownership and thinking broadly and creatively about every aspect of projects they work on, engineers have a chance to enrich the lives of the people that their work touches.

The initial goal of the partnership between Lehigh and KEEN includes training of all Lehigh undergraduate engineering teaching faculty in the pedagogy of active collaborative entrepreneurial minded learning and to incorporate these teaching methods into their core engineering courses. Most importantly, the ultimate goal is to reach 100% of the engineering graduates at Lehigh with KEEN's entrepreneurial mindset.

"We're leveraging KEEN training to influence the way faculty create their curriculum," says John Ochs, a professor of mechanical engineering, founder and director of Lehigh's award-winning Technical Entrepreneurship capstone and master's program, and a KEEN Faculty Mentor. "All undergraduate engineering students should be exposed to KEEN's EML techniques and have the chance to incorporate them into their educations and careers. So, we intend to infuse EML in some way into all core courses across every major."

"We are very broad about how we want this mindset change to occur," he says. "We are providing a roadmap, and cultivating a community of like-minded faculty who will integrate EML across Lehigh's engineering landscape."

Sue Perry, a professor of practice in Lehigh's bioengineering department, has been working with faculty on implementing KEEN principles within the bioE undergraduate program.

"We are examining current courses to identify overlap in specific topics between early and advanced classes, and developing modules through which faculty can create context connections in earlier courses," says Perry. "We intend to create a learning continuum so students retain fundamental principles and have the tools to strengthen their knowledge as they progress through the curriculum."

"For example," she continues, "we are using the human cardiovascular system as a way to create context across the portion of our curriculum dedicated to fluid dynamics. In sophomore level classes, we'll introduce the concepts of biomaterials and biomechanics by having students design and 3D print artificial heart valves in one class, then test them for function and output in the next. Our junior-year fluids course examines the principles of fluid dynamics of the cardiovascular system—and by that point, students will have context for the theory we're presenting, and will be prepared to think more deeply about how they can apply their knowledge."

"If we can use active, project-based learning to create connections," she continues, "we will create a greater depth of understanding from start to finish in the curriculum."

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LEHIGH FACULTY CURRENTLY ENGAGED IN KEEN

Recognition for computer science innovation

RESEARCH RECOGNITION

Professor Mooi Choo Chuah has been elected as a 2017 Fellow of the National Academy of Inventors (NAI).

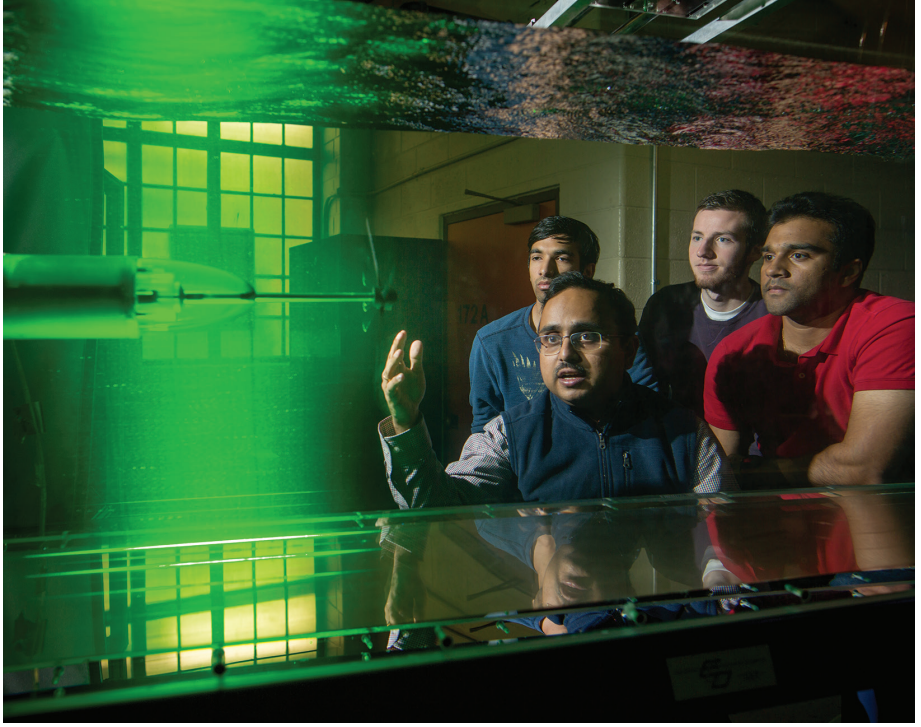
Election to NAI Fellow status is "the highest professional distinction accorded to academic inventors who have demonstrated a prolific spirit of innovation in creating or facilitating outstanding inventions that have made a tangible impact on quality of life, economic development, and the welfare of society."

"Mooi Choo is a natural choice for the NAI Fellows program," says Victor Lawrence, a Distinguished Research Professor from Stevens Institute of Technology who nominated Professor Chuah for the fellowship. "Ideas from some of her inventions form the basis of standards that govern several crucial technological areas in mobile and wireless communications. Moreover, she is not only an innovative researcher, but is also a great role model for young women considering STEM careers."

Chuah, a professor of computer science and engineering, joined Lehigh's faculty in January 2004 after 12 years with Bell Labs. Widely regarded as one of the world's leading researchers and inventors in the field of wireless data and mobile systems, she holds 63 U.S. and 15 international patents, most of them for innovations with wireless LAN (Local Area Network)-based systems, and for features that enable quality of service, mobility management in WLAN and 3G systems. Some of her past Ph.D., M.S. and undergraduate students are now working at top technology companies such as Google, Microsoft, Samsung Research, and Snapchat.

At Lehigh, Chuah's lab maintains active research in the design of secure mobile data systems, mobile healthcare, deep learning based systems for vision-based activity recognition, health care data mining, and resilient smart grid control networks. Yet her research interests allow her to find avenues where her team can contribute in some surprising areas.

"In my work," she says, "I'm always looking to solve problems that I know will have some kind of positive social impact."



Arindam Banerjee (right) and his team explore fundamental issues related to space and scale interactions in turbulent flows.

Understanding the impact of marine hydrokinetics

A deep dive into the harvesting of tidal energy

Arindam Banerjee, an associate professor of mechanical engineering, is pursuing a three-year grant from the National Science Foundation to study the impact of free-stream turbulence on tidal turbines.

Tidal energy is a form of hydropower that converts the energy obtained from tides into electricity. As a form of sustainable energy, tides are more predictable than the wind and sun, and thus intriguing to engineers pursuing greener forms of generating electricity.

Tidal energy is produced with a tidal energy generator, which functions like an underwater wind turbine. The turbine captures the ebb and flow of the water, turning the turbine's blades to power a generator and produce electricity.

Banerjee and his group will investigate the performance and durability of tidal turbines by mimicking the turbulent marine environment in a laboratory setting through the use of an active turbulence generator. The proposed work will address several outstanding scientific challenges that need to be overcome in order to increase the performance of the turbines and accelerate the technological readiness level of these devices.

With more than 50% of the population living within 50 miles of coastline, there is vast potential to provide clean, renewable electricity to communities and cities across the United States using marine and hydrokinetic (MHK) technologies. Through the commercialization of this energy technology, tidal energy resources have the potential of generating 300 terawatt-hours per year in the United States, powering roughly 27 million homes.

Banerjee's interest and expertise lie in multi-scale fluid-dynamics with emphasis on energy and biological systems. His research goal is to enhance our limited understanding of fundamental issues related to space and scale interactions in turbulent flows.

Banerjee earned a bachelor's degree in mechanical engineering from Jadavpur University in Calcutta, India, a masters in mechanical engineering from the Florida Institute of Technology, and a doctorate in mechanical engineering from Texas A&M University. His postdoctoral study was at Los Alamos National Laboratory in New Mexico. Banerjee is the recipient of the prestigious NSF CAREER Award (2014), the Joel and Ruth Spira Teaching Excellence Award (2015) and the Libsch Early Career Research Award (2017).

Atomistic models reveal surprising order

Shedding light on structures that form when atoms segregate

Scientists in the United States and China have announced a discovery that they believe could enable the engineering of alloyed materials that are stronger, more ductile and possess superior electrical, magnetic and physical properties.

Writing in *Science*, the nation's leading scientific journal, the researchers said they had found a surprising degree of order in the interior grain boundaries—the interfaces between crystalline grains—that determine the properties of polycrystalline materials such as metals and ceramics.

Scientists have traditionally identified two categories of grain boundaries in polycrystalline materials, says Martin P. Harmer, the Alcoa Foundation Professor of Materials Science and Engineering at Lehigh.

Special grain boundaries occur at a relatively small fraction of the internal interfaces of a material when adjoining lattices (the 3D arrangement of atoms inside a crystal) of individual grains join together with little mismatch and form a periodic or patterned superstructure.

General grain boundaries are more common and occur in the interior of a material when there is a large misfit between adjoining grains and no matching of the adjacent crystal lattices.

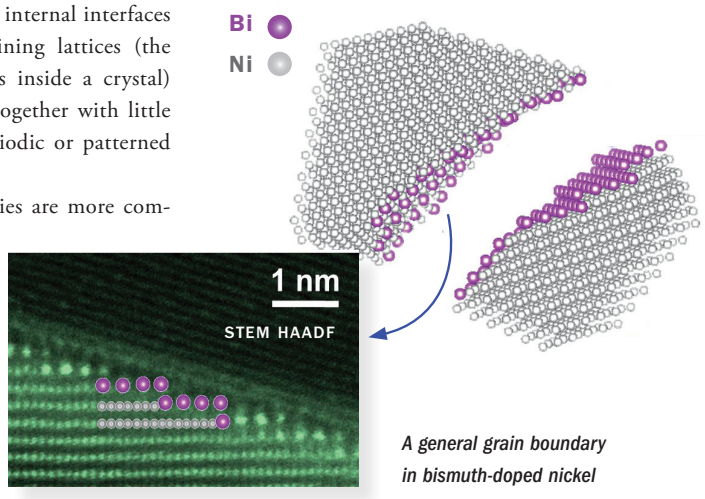
"General grain boundaries tend to be the weak regions of an engineering material," says Harmer, one of the coauthors of the *Science* article. "But while special grain boundaries typically have much better properties, general grain boundaries are more prevalent, and therefore more important, because they determine the bulk properties of a material."

General grain boundaries have been difficult for scientists to study, says Harmer, because they are harder to access than special grain boundaries and because they can form a wide variety of possible configurations.

Using atomic-resolution electron microscopy and numerical calculations, Harmer and his colleagues have succeeded in characterizing 12 randomly chosen general grain boundaries in polycrystalline nickel doped with bismuth. The six-year project has been funded by the Office of Naval Research through its Multidisciplinary University Research Initiative (MURI).

The researchers found that bismuth atoms adsorbing, or segregating, at the general grain boundaries of nickel formed superstructures whose weak bismuth-bismuth bonds at critical junctures caused the alloy to become brittle.

"This discovery," they wrote in *Science*, "shows that adsorbate-induced superstructures are not limited to special grain boundaries but may exist at a variety of general grain boundaries, and hence they can affect the performance of polycrystalline engineering alloys."



A general grain boundary in bismuth-doped nickel

"We believe that, for the first time, we have discovered superstructures at general grain boundaries in a metal alloy," says Harmer. "Until now, this had been a very hidden phenomenon in metals.

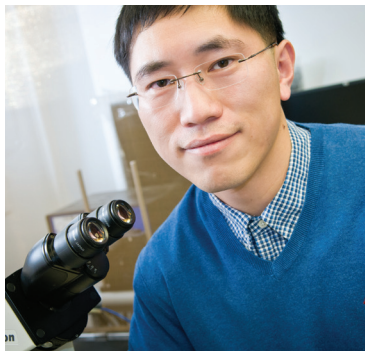
"This breakthrough helps us understand why, in the case of nickel-bismuth, the alloy embrittles. But beyond that, there will potentially be superstructures in general grain boundaries which enhance a material's performance, strength and ductility.

"New tools and models make it possible to see things in general grain boundaries that we couldn't see 10 years ago. These are changing how we think about materials, and how we engineer them."

Liu named ASME fellow

RESEARCH RECOGNITION

Yaling Liu, who has spent much of his career applying the principles of fluid mechanics and nano-engineering to biology and medicine, has been named a fellow of the American Society of Mechanical Engineers, one of the top honors in his field. ASME, a professional society founded in 1880, has more than 130,000 members in 151 countries.



Liu, an associate professor of mechanical engineering and also of bioengineering, has developed testing and diagnostic tools that mimic the behavior of body tissue, enable the early detection of cancer and evaluate the targeted delivery of medicine at the nanoscale. He has received funding from the National Science Foundation (NSF), the National Institutes of Health (NIH), the National Institute of Biomedical Imaging and Bioengineering, and Oak Ridge Associated Universities.

In one NSF-funded project, Liu and his students have developed a cheap, portable device that detects cancerous tumors before a patient feels symptoms. The device, which Liu calls a "lab on a chip," isolates the relative handful of tumor cells that break free from the site of a tumor and circulate among billions of normal blood cells in a single milliliter of blood. Because of its size and relatively low cost—less than $5 per unit—the device shows promise for use in developing countries.

The lab-on-a-chip device, Liu said, can identify cancer cells before a tumor grows large enough to appear on an MRI and can thus help detect cancer in its very early stages when it is easier to treat. The device can also monitor the progression of a tumor and the effectiveness of treatment. Liu and his group are working with Lehigh Valley Hospital on a clinical trial to test the device on melanoma and renal cancer patients.

The long-term goal, said Liu, is to predict drug performance under disease conditions and thus allow the directors of pre-clinical drug trials to "mitigate scientific, financial and temporal risks when transitioning candidates from high-throughput evaluations to animal models."

Liu has published 65 articles in peer-reviewed journals and more than 100 conference proceedings and abstracts. He is also the author of seven book chapters. His research has led to the awarding of three U.S. patents.

LIFTING THE TEAM HIGHER

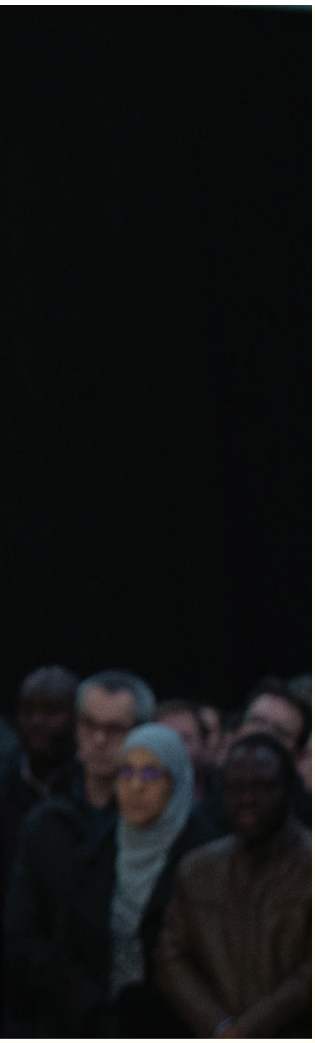
Engineers, steeped in collaboration and communication, are built to lead

Lehigh alumna Judith (Judy) Marks '84 is President of Otis Elevator Company, a unit of United Technologies and the world's leading manufacturer and service provider of elevators, escalators and moving walkways. Marks landed her first management job at 23 and went on to senior leadership roles at three global icons—IBM, Lockheed Martin and Siemens AG. She was serving as CEO of both Siemens USA and Dresser-Rand, a Siemens business, when recruited to run Otis in 2017. Her experience spans multiple disciplines across aerospace and defense and the data and industrial technology worlds, and she has led successful corporate development and strategic growth in emerging and mature platforms and products. Marks holds a B.S. in electrical engineering from Lehigh. She has served on the Dean's Advisory Council and has supported several Lehigh initiatives aimed at increasing diversity among the science, technology, engineering and math disciplines.

Q: ***Is there a difference between leadership and management?***

A: Yes. Managers guide and direct the accomplishment of work. Leadership requires vision and judgment. A leader needs to have a willing and engaged team that is aligned and empowered to achieve the objectives of the company. To me, a good leader has the ability to make decisions—and makes them. It's someone who surrounds himself or herself with outstanding people, empowers those people and holds them accountable.

Importantly, a leader is someone who has the ability to lead through change, because change is the norm. Change can be exciting. It is for me. I see it as generally positive, even exhilarating. But it poses challenges for the people in your organization. Not everyone is comfortable with it. So a leader needs to focus on people and change management to successfully guide them from the old to the new.



Judy Marks '84 says that good leaders know how to take calculated risks and are exhilarated by change.

Q: *Are technology companies finding enough qualified people for careers in the STEM disciplines?*

A: When I talk about STEM careers, there are those you pursue at the university level and those you pursue post-high school. In today's workforce we really do have a challenge in terms of access to what I would call digitally literate, technologically literate employees, especially in some of the craft areas, because technology permeates every job in today's economy. At Otis we've got 33,000 mechanics globally who are servicing our elevators. Well, our elevators are smarter; they're rich with data from our controllers and sensors. Our mechanics now have sophisticated tools with them. These are not just mechanical skills anymore. They are mechanical and technology skills. Other industries have similar challenges.

Q: *Does engineering prepare people for leadership roles?*

A: Engineers bring a great analytical approach to problem solving and to leadership. Engineering is a strong foundation for today's business environment. Engineers need to continue to learn to become well-rounded leaders. They need to add business and finance to their skill set. The other element is engaging with others. I think engineers can bring teams together to solve problems and innovate like no other group of people I've ever seen. To do that, they do need soft skills—collaboration, engagement, achieving alignment on objectives, communication. You don't really learn those in the classroom, but only by working with others.

My engineering background has certainly played a pivotal role in my career. That's why I encourage young women to go into engineering and the sciences. It provides an excellent foundation for business and the professions. It gives you the tools for solving problems. Without that I might not have gotten the opportunities I've had.

Q: *What should we be doing to address this need?*

A: We need to raise the knowledge base of all students and future employees, as they go from K through 12 and on to community colleges or universities. Once they're in industry, we need to provide continuous learning. One thing we at United Technologies do to encourage STEM education in the schools is to sponsor robotics competitions. For our own people, we provide funding and accessibility to getting degrees. We have programs internally to help them learn technology to make a contribution. We bring people together in communities of interests to share challenges and to learn together. It's a whole spectrum of STEM commitment that starts with K through 12 and never ends as part of continuous learning at the company.

Q: *Diversity is an important issue for you. Are technology companies having success in creating diverse workforces?*

A: I think there's been some success. There's room for more. All companies need to address diversity. It's the future of their business. I don't understand why a business wouldn't want to be able to recruit and retain from multiple communities and diverse employees. Because with diversity, you get diversity of thought. People approach things differently because they come from different backgrounds. That drives innovation and problem solving. That's the power of diversity: different solutions, different thoughts and different voices being heard at the table.

Q: *Does diversity affect the bottom line?*

A: Absolutely. For example, there is growing evidence to support the business case for gender equity. Last year, the Peterson Institute and EY conducted a study that looked at nearly 22,000 publicly traded companies. They found that companies with women in at least 30 percent of leadership positions had a 6 percent higher net profit margin. That is definitely a bottom-line impact.

Q: *Have you been involved in diversity?*

A: Yes, both inside and outside our company, because I believe I have a responsibility. People have come before me and created an environment where I can succeed. I believe I have a responsibility to the next generation of leaders to help create an environment where they can succeed. I also make it a point to share the lessons I've learned with industry groups externally, and I certainly do that inside the company.

Q: *Any final thoughts for people moving into leadership positions?*

A: Leadership transitions are challenging, but rewarding. Here are some things that I have found helpful: trust your instincts; admit what you don't know; listen; communicate—three times as much as you think you should; stay with what works; and take time to celebrate successes. Most of all, remember that you're not leading a company—you're leading people.

Q How important is risk-taking and "getting comfortable with the uncomfortable" in early career choices? Was that challenging for you?

Sure. I think when you're trained as an engineer, as I was at Lehigh, you're taught that when you work hard enough at a problem, you can solve it. But in industry, problems have other dynamics and dimensions to them. You need to learn how to collaborate and how to get engaged. Taking risk is part of that. I advise people to calculate that they're taking a risk and live with the consequences. But don't take risks wildly.

EXPERIENCE OF A LIFETIME

BY **RICHARD LALIBERTE**

THE EDUCATIONAL IMPORTANCE OF FINDING **PASSION**, DOING **HANDS-ON PROJECTS**, AND **MAKING AN IMPACT**

The photo anchoring a web page for Lehigh University's Baja SAE team ostensibly shows a set of impressively large trophies—a collection suggesting a tale of competition and victory. But the picture's other details suggest an even deeper, more multilayered story. The prizes perch on a hand-built, dune-buggy-like, off-road vehicle framed by roll bars and sporting fat, gnarly tires.

Designed and built by Lehigh students for competitive events sponsored by the Society of Automotive Engineers, the vehicle sits on a scrubby patch of grass off a dirt trail and—in sharp contrast to the gleaming swag—is caked from top to bottom with thick mud. Implied in this picture-worth-a-thousand-words are a backstory of passion, effort, grit, technical know-how, collaboration, execution, and success.

All of those elements came into play during two years in which the student team designed, manufactured, and tested an off-road vehicle that they then took to two 2017 competitions, in Kansas and Illinois. At each event, Lehigh students pitted their vehicle against those from about 100 teams from around the world—some from larger schools with major corporate sponsorships—in tests of technical requirements, engineering, and cost-effectiveness. Vehicles that passed a technical inspection also competed in dynamic events such as tests of traction, suspension, acceleration, maneuverability, and hill climbing, culminating in a four-hour endurance race through obstacles like jumps, hairpin turns, rugged terrain, and creeks. Hence the mud.

At the Kansas event, the Lehigh team shook up the world by taking first place in dynamic competition and fifth place overall. In a team video, students look back on their experience from its earliest moments. "We were thinking about: What were we getting out of our time at Lehigh?" says recent mechanical engineering graduate Jonathan Whitcraft '17. "We thought doing a project like this would supplement everything that we're learning in the classroom terrifically, and we would learn so much more than we ever could have even imagined [we'd learn] in the classroom, which I think is absolutely true."

The students were tapping into a concept that's becoming increasingly important at the P.C. Rossin College of Engineering and Applied Science and across Lehigh University as a whole: experiential learning. "I've been in higher education for more than 30 years, and we're in a real changing environment when it comes to how undergraduate engineering education is conceived and delivered," says Steve DeWeerth, Professor and Dean of the Rossin College. "We're moving from a didactic, faculty-centric model of teaching in which a teacher dictates information in a classroom setting for 50 minutes, to a student-centric model of learning fueled by the concept of creative inquiry."

While classroom teaching remains important, students increasingly have opportunities to find hands-on interests and projects for which they are truly passionate. These build on what they're learning in the classroom, have a tangible impact in the world and prompt them to think about where their experiences and classroom learning together might lead in their careers.

"That's the essence of experiential learning, and I would argue that opportunities for students on this front over the last decade or so have just blossomed," DeWeerth says. "We're learning that *how* we teach matters as much as *what* we teach, and we're finding ways to facilitate these opportunities."

Real-world problem-solving

Experiential learning differs from more traditional forms of pedagogy in part by allowing students to solve real-world problems. "It's not as much about solving closed problems where there's perfect information and a given solution that the teacher already knows," says Greg Tonkay, Professor and Associate Dean for Academic Affairs. "It's more about solving open-ended problems in which students can arrive at different solutions."

That vision more closely mirrors what students will encounter once they graduate.

International service projects through Lehigh's Bridges to Prosperity chapter (above) offer insight into real-world applications of engineering.

"The world isn't black-and-white like a high-school calculus test," DeWeerth says. "Real-world problems almost never have exact answers, otherwise they're not actual problems. Yet that black-and-white approach is typically how we've educated in the past. Experiential learning avoids so-called toy problems. The real world is: Here's a problem, we don't know what the answer is, there isn't a perfect answer, but there are some good answers—and bad answers—and you have to go explore that space," he says.

Computer science student Lena McDonnell '17 (right) leads Team Soterra in developing its personal safety device.

The hope is that from the start of their Lehigh education, students will consider what open-ended, real-world questions look like along with what critical thinking skills and interdisciplinary approaches are needed to provide effective answers. "To do that, we need to blur the lines between what's in the curriculum and what's out," DeWeerth says. Experiential learning isn't meant to be a "co-curricular" add-on. "I don't want to draw a line between experiential learning on one side and classroom learning on another," DeWeerth says. "They are parts of an integrated whole."

Experiential opportunities

Pathways to experiential learning already exist at Lehigh. Industry internships have long been a way for students to gain practical experience. "They're becoming almost essential for us now," DeWeerth says. Student research with faculty—common among graduate students—is becoming increasingly common among undergraduates. A large percentage of students take part in international experiences that allow them, for example, to apply classroom knowledge in disciplines such as engineering or computing to solve problems in developing countries. Service learning opportunities enable students to apply scientific or engineering skills to help communities or address social issues. Competition teams and clubs such as Baja SAE or Formula SAE—a similar club that designs and builds a Formula-style race car—encourage students to apply engineering and critical thinking skills in scored efforts that participants hope will outperform those of rival teams.

"MY GOAL IS TO HAVE **100 PERCENT** OF OUR UNDERGRADUATE STUDENTS ENGAGE IN MEANINGFUL **EXPERIENTIAL LEARNING** DURING THEIR EDUCATION AT LEHIGH."

—Stephen P. DeWeerth, *Dean*

Some projects meld multiple forms of opportunity. Combining service, competition and international experience, one Lehigh group—Team Soterra—is among 20 out of 85 teams from around the world that advanced to the semifinal round of the international Anu and Naveen Jain Women's Safety Prize offered by the XPRIZE Foundation, a nonprofit that encourages innovators to develop technological solutions to pressing problems. The Lehigh team is developing a handheld device that allows users who feel threatened to quickly alert preselected personal contacts or police. The device employs a Bluetooth mesh networking solution along with GPS technology that will pinpoint a user's location with 50 times greater accuracy than a triangulated cell signal. Students are developing the device in hopes of reducing violence against women, especially in areas of the world where cell phone ownership is low.

A number of Lehigh initiatives encourage these kinds of experiential activities. The Mountaintop Initiative allows students to work freely across disciplines in pursuit of innovative, creative answers to open-ended problems and questions. The Baker Institute for Entrepreneurship, Creativity and Innovation fosters and champions entrepreneurial culture, nurtures creative thinking, and provides opportunities and resources for students across disciplines to put innovative ideas and technologies into practice.

Currently, the Rossin College is moving to incorporate experiential learning more fully into its curricula. "My goal is to have 100 percent of our undergraduate students engage in meaningful experiential learning during their education at Lehigh," DeWeerth says. "We're putting together a process to make that happen."

Expanding vision

Capstone Design requirements for engineering programs have long provided opportunities for students to gain real-world experiences, often driven by the needs of an external client or partner with a problem to solve. For example, Lehigh's award-winning Technical Entrepreneurship (TE) Capstone program gives juniors, seniors and graduate students in engineering, business and the design arts an opportunity to work in interdisciplinary teams to design, fabricate, and produce products for industrial partners. "We're moving now toward doing more design projects in the first year," DeWeerth says.

According to DeWeerth, TE Capstone is a model for growing Capstone Design across the College due to its client-driven emphasis on real-world problems and its interdisciplinary approach.

"It sounds a bit hyperbolic, but some of the hardest and most interesting problems are at the interface of disciplines these days," he says. "We see this in industry, and we hear it from people who hire our students. Our graduates will be working in interdisciplinary teams when they leave campus, and they will benefit immeasurably from participation in a culture of interdisciplinary excellence while they are here."

Building and emphasizing interdisciplinary team science

and experiential learning—whether faculty-led research, international opportunities, industry experience, service learning, or competition teams—not only helps students learn; it also supports broader strategic goals of growing Lehigh's research output, productivity, impact, and reputation.

To further develop a culture in which students search for and explore passionate interests that can focus and drive their academic pursuits, the college plans to begin a peer-mentoring program in fall 2018. Building on a university-wide program, student mentors who have participated in experiential learning will help introduce the idea to first-year students.

"The goal is that by the end of the first semester, incoming students will each write an experiential learning plan that starts them thinking about the opportunities that are available and what they hope to do during their four years at Lehigh," DeWeerth says.

Plans drawn up so early in an education are expected to change. But whatever journey students go on, by the end of four years it's hoped they will have portfolios of experiential projects that show the fruits of their education beyond deskbound classes and a grade point average.

"A Capstone Design project could be involved, or if they're on an SAE team, they can say, 'Look, here's the car my team worked on and here's the part I designed—and we got fifth place nationally,'" DeWeerth says. "That helps students define their own stories. It's important for them to start thinking in terms of 'Who do I want to be as an engineer?'"

Engineering identity

Experiences help establish personal identity, and experiential learning is thought to connect education to a deeper sense of who a person is. DeWeerth maintains that thinking about opportunities for experiences early in an education tends to put students in a different mindset that's less "how do I get a degree in engineering?" and more "What does it mean to be an engineer?"

"We need to start feeding students that mindset even before we start feeding them skillsets and knowledge," DeWeerth says.

Thinking in terms of meaning, passion, and opportunity often leads to a more creative and entrepreneurial outlook. That's a key goal of curriculum design encouraged by the Kern Entrepreneurial Engineering Network (KEEN), a collaboration of colleges and universities dedicated to developing an entrepreneurial mindset in engineering students. KEEN, an initiative of the Kern Family Foundation, has provided funding to Lehigh for three years.

"When we finish the latest phase of our grant, we will have more than half of the faculty members in our college involved in developing or applying entrepreneurial mindset learning in their courses," DeWeerth says. "They're asking, 'How do I expand the way I educate beyond standing in front of a classroom three times a week?' They're being creative in their pedagogy, and the fact that it has impacted so much of our faculty means we're making a cultural change."

The shift has drawn in students as well. "At Lehigh, we've paired faculty members with students to develop activities around what students feel would be helpful to them as learners," Tonkay says. "We're actually starting from the student's point of view and working up."

Promoting this entrepreneurial mindset may inspire students to develop products and start companies. "This is an area where we've seen rapid growth across the country," DeWeerth says. "We have some of that at Lehigh and I think it will continue to grow both here and elsewhere.

Whether products or companies succeed or not, learning an entrepreneurial mindset will permeate whatever a student's career becomes."

If an idea does succeed, students have ownership. "Even if university resources or fabrication facilities are involved, as long as it wasn't funded by the university or federal sponsors, students are able to use their intellectual property," DeWeerth says. "They own their ideas." Like experiential learning as a whole, that's a win for Lehigh, he says: "Our goal is the success of our students."

Students benefit from such co-curricular activities as LehighSiliconValley (top), the University's innovative Mountaintop Initiative (bottom left), and interaction with Lehigh's powerful network of industry partners (bottom right.)

AN INTERDISCIPLINARY HAT TRICK

Do you believe in research miracles? YES!

BY **MANASEE WAGH**
AND **CHRIS LARKIN**

"A 100% success rate is an impressive feat for any university, and a testament to the strength of Lehigh's interdisciplinary culture."

—John Coulter

ACROSS AN ARRAY OF COMPETITIVE ENDEAVORS THAT INCLUDE SCRABBLE, CRICKET, AND ICE HOCKEY, the scoring of three goals in a single contest is met with much fanfare.

As any faculty researcher will tell you, grant writing is indeed a contact sport, and three 'goals' in a single year is equally applause-worthy.

Very few research funding opportunities are more competitive than the National Science Foundation's (NSF) annual Major Research Instrumentation (MRI) program. In the 2017 MRI cycle, Lehigh University took three shots on goal—and buried all three in the back of the net.

A 100% success rate is an impressive feat for any research university, says John Coulter, Professor and Senior Associate Dean for Research in the Rossin College, and a testament to the strength of Lehigh's interdisciplinary culture.

"MRI grants support the development of shared core facilities—sophisticated instruments that will advance the work of multiple research teams around campus," he says. "They will also enable further collaboration with our external colleagues, facilitating further research progress across disciplines and organizations."

TEAM #1

ENVIRONMENTAL X-RAY PHOTOELECTRON SPECTROMETER

Israel Wachs, Himanshu Jain, Jonas Baltrusaitis

The Environmental X-ray Photoelectron Spectrometer (E-XPS) performs nanoscale surface analysis of materials in a wide variety of environmental conditions, a technological feat in its own rite. Ordinarily, says Israel Wachs, it is very difficult to place samples in realistic conditions.

"Advanced functional materials possess unique surfaces and interfaces that find widespread use, such as

generation of clean H_2 fuel via photocatalytic splitting of water, solar energy storage, semiconductors, wear of materials' surfaces, biofuel production, water treatment, biomolecules in their native wet environments, and medicine," says Wachs. "Successful applications require detailed information about the surfaces and interfaces of these materials in different environmental conditions."

"The E-XPS will give Lehigh researchers unparalleled access to surface elemental composition and chemical state information about such interactions in different environments—gas-solid, liquid-solid, and liquid-gas—over a wide range of temperatures. This is incredibly sophisticated equipment, and it is difficult for most universities to obtain such equipment without support like this from the NSF."

According to Wachs, use of the E-XPS for surface analysis will overcome shortcomings of traditional XPS instrumentation that can only operate under ultra-high vacuum pressures. With this "near ambient pressure" capability offered by the new generation of E-XPS spectrometer, Wachs envisions research activities with the potential to advance the fundamental science and design of advanced functional materials.

"Many materials' properties and functions are determined by the arrangement of their atoms—the composition, structure, and electronic properties at the materials' surface," Wachs explains. "With the E-XPS, Lehigh researchers have a more powerful tool than ever before in examining and understanding the molecular structure at the top layer of a material."

TEAM #2

HIGH PRESSURE SPATIAL CHEMICAL VAPOR DEPOSITION REACTOR DEVELOPMENT

Nelson Tansu, Siddha Pimputkar, Jonathan J. Wierer, Volkmar Dierolf, Nicholas C. Strandwitz, Renbo Song

An interdisciplinary faculty team associated with Lehigh's Center for Photonics and Nanoelectronics (CPN) is using its MRI support to create a High Pressure Spatial-Chemical Vapor Deposition (HPS-CVD) reactor, intended to be ready to grow new materials beginning in January 2019. The instrument will be managed by CPN's technical staff, and it will be housed in the Smith Family Laboratory, a 12,000 ft^2 facility that enables semiconductor epitaxy, nanofabrication, and advanced device characterization.

This system will enable new capabilities in material synthesis that includes growth under extremely high-pressure conditions, growth under extremely high temperatures, the ability to integrate new elements, and the ability to integrate highly dissimilar materials.

According to Nelson Tansu, core Lehigh faculty working in III-nitrides and new oxide/oxynitride wide bandgap semiconductors are highly productive, with more than 90 journal papers published at Lehigh over the past five years.

"We are truly excited to have the opportunity to build a next generation reactor with the capability of growing new materials under extreme conditions," says Tansu, who also serves as director of CPN. "A reactor that can grow unconventional III-nitride semiconductors, oxynitride materials, and potentially integrate them with other two-dimensional layered materials, will allow us to make novel and promising materials, to answer fundamental questions about them, and to use them to build groundbreaking devices."

TEAM #3

500 MHZ NUCLEAR MAGNETIC RESONANCE SPECTROMETER

K. Jebrell Glover, Damien Thevenin, Bryan Berger, Sabrina Jedlicka, Stephen Dunham (Moravian College), and Matthew Junker (Kutztown University)

Nuclear Magnetic Resonance (NMR) spectroscopy is one of the most powerful tools available for the structural study of molecules. It is used to identify unknown substances, to characterize specific arrangements of atoms within molecules, and to study the changing interactions between molecules in solution. With support from the MRI grant, K. Jebrell Glover's lab has recently improved the signal-to-noise of its existing 500 MHz NMR spectrometer with the addition of a so-called "cold probe" that uses liquid helium to cool the system's electronics, and a new user console to make the device even more powerful.

"The NMR spectrometer allows you to get information on every single atom," he says. "For protein work, this added sensitivity is very, very important and represents the latest platform."

Glover specializes in the structure of membrane proteins, specifically caveolin, found on the surface of cells and involved in making special pits, called caveolae, in the cellular membrane.

"This protein is implicated in heart disease, cancers, muscular dystrophy and Alzheimer's' disease," says Glover an associate professor of chemistry with the College of Arts and Sciences, "so developing our understanding of caveolin is very important."

Glover adds that the instrument will be available to students and researchers who need to examine materials on such a small scale.

"This ensures that the impact of the NSF's investment is as significant as possible," he says.

"Success," says Alan Snyder, Vice President and Associate Provost for Research and Graduate Studies, "means that our faculty teams have convinced peers in their fields that these instruments belong at Lehigh."

 BY **RICHARD LALIBERTE**

THE SKY IS THE LIMIT

"The best interdisciplinary science comes from the realization that there are pressing questions or problems that cannot be adequately addressed by people from just one discipline."

—*Nature* magazine

INTERDISCIPLINARY RESEARCH INSTITUTE ESTABLISHED IN NEW HUB OF LEHIGH INNOVATION

The topic of interdisciplinary research must be pretty timely if the journal *Nature* dedicates a special issue to it, as it recently did. In an opinion piece, the editors outlined the impracticality of attacking the globe's most pressing problems from scientific departments encased in silos. "The best interdisciplinary science comes from the realization that there are pressing questions or problems that cannot be adequately addressed by people from just one discipline," the editors wrote. "An interdisciplinary approach should drive people to ask questions and solve problems that have never come up before."

Lehigh is responding to the demand for innovative approaches to scientific inquiry with the creation of three inaugural Interdisciplinary Research Institutes (IRIs) designed to bring together top scholars across the university and their external partners to pursue large-scale, transformative research. The institutes are the fruit of a faculty-led Envisioning Process, which was among the first initiatives launched by Steve DeWeerth, Professor and Dean of the Rossin College. The process tasked faculty from Rossin and the other Lehigh colleges with evaluating and identifying strategic strengths, opportunities for growth, and specific interdisciplinary themes for which Lehigh is uniquely positioned to assume a global leadership role.

The envisioning team—looking outward to find the most vital and exciting research areas and inward to mine Lehigh's native strengths—identified the themes for the inaugural Institutes: the Institute for Functional Materials and Devices (I-FMD); the Institute for Data, Intelligent Systems, and Computation (I-DISC); and the Institute for Cyber–Physical Infrastructure and Energy (I-CPIE).

Each Institute and its faculty will incubate and catalyze big ideas, will pursue large-scale extramural funding, and will promote the impact and visibility of Lehigh research to the world. The University has committed to providing interdisciplinary facilities, "venture" funding, and Institute staffing to support the success of these endeavors. In addition, the Rossin College is supporting the growth of these Institutes through a commitment to strategic faculty hiring to enhance and extend Lehigh research in these areas.

The new Institutes will position Lehigh as a thought leader and destination across these themes. Hector Muñoz-Avila, I-DISC co-director and Professor of Computer Science and Engineering, also foresees that the Institutes' portfolios will dovetail with each other. "As an example," he says, "the work of I-DISC will have broad areas for collaboration with I-CPIE and I-FMD, in the context of the increasingly-crucial role that data and computation plays in those domains."

I-DISC's domain will extend across intelligent systems, data, computation, optimization, robotics, machine learning, and related fields. "Our team includes faculty from across Rossin College, as well as government relations, biological sciences, and economics. We identified data, intelligent systems, and computation as places where Lehigh already had great strength that could be put in a position to do more integrated research and have a significant impact," says Muñoz-Avila. "We have seen in recent years a data revolution in terms of the kind and amount of data that is available, and with advances like the Internet of Things there will only be more."

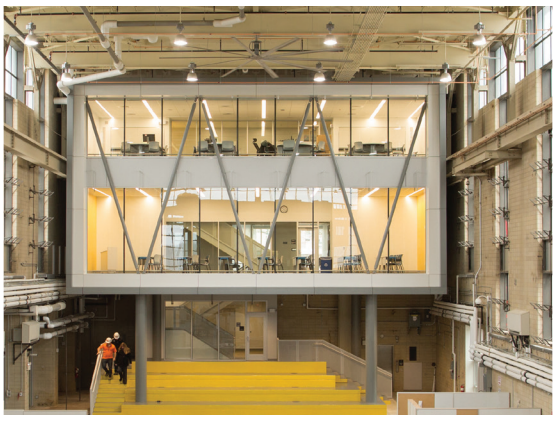
Hector Muñoz-Avila (left) serves as co-director of I-DISC; student participants in Lehigh's Mountaintop Initiative use Building C's high bays for a variety of real-world projects.

The Institute has a running start in part because it was preceded by Lehigh's Data X initiative, a cross-curricular program that infused interdisciplinary, data-centric research throughout the university. Part of Data X's mandate was a significant number of faculty hires, and as the Institute gears up, more are in the pipeline. "Lehigh has committed significant resources to support the research institutes, and will be doing more faculty hiring in strategic areas such as data analytics, cyber–physical systems, and robotics, which will augment the numerous Data X hires over the past few years," says DeWeerth.

The fundamental demand of the research institutes is that they be foundational in their structure as well as their deliverables. "I-DISC will create bridges across the university and be a fertile space for collaborative work, and the research we do will attack at the root some of the most pressing problems in technology and society," says Katya Scheinberg, I-DISC co-director and Harvey E. Wagner







(Above left) The dramatic renovation of historic Building C includes new spaces for learning, conducting research, and collaborating; (above right) Team TRIPODS integrates computer science, statistics, and applied mathematics.

Professor of Industrial and Systems Engineering. "It's meant to be for the whole university, and we expect that the research it produces will generate solutions with broad applications. It may be engineering-focused, but it won't be engineering-centric."

Existing partnerships with Lehigh's College of Business and Economics (CBE) provide an example of how such cross-pollination creates benefits. "We already have two specific people who were hired in consultation with the computer science department, and we have made other hires of people who combine business and data and computation in their research and teaching areas," says Georgette Chapman Phillips, the Kevin and Lisa Clayton Dean of the College of Business and Economics. "Our relationship with computer science gives our students the opportunity to have high levels of expertise in data science in addition to business. From a research perspective, I-DISC will push our faculty to the forefront in this area. This field is a perfect example of how Lehigh works well across colleges."

The environment for collaboration doesn't happen by itself, states a 2016 report on interdisciplinarity commissioned by the Global Research Council. The study, in outlining the increasingly vital role that interdisciplinary research will play in resolving society's grand challenges, specifically detailed that creating conditions for collaboration was of primary importance to the success of interdisciplinary research programs. "Much of the literature argues that funders should not assume that the conditions required for interdisciplinarity can happen naturally without proactive support," reads the report. "Instead, consideration should be given to the practical steps and mechanisms necessary to foster and support research across disciplinary boundaries."

The newly renovated Building C on the Mountaintop Campus, which will house the Institute, was specifically designed to be a catalyst for just that.

A (R)EVOLUTIONARY OVERHAUL

Built both for comfort and speed, Building C has broad, clear sight lines, glass and steel encased classrooms and offices, and panoramic views of the Lehigh Valley; it is also wired with up-to-the-minute data and networking connectivity. There are plenty of welcoming meeting places where you might run into faculty from other fields, and have the kind of impromptu conversations that lead to unexpected insights. The building sports a feature called Mixing Boxes, glass-enclosed meeting rooms that overlook the expansive bays. It's not all glam though. In a reverent nod to the manufacturing history of the former Bethlehem Steel structure, architects preserved many of the original features of the building, including the shell which houses the more contemporary internal fixtures.

If the walls could speak, they would say that this is a place where work gets done. Lab spaces and bays will facilitate the kind of experiential learning that Lehigh is known for and that students demand, and the overall feeling of Building C is an agreeable balance of gleam and grit, an homage to an industrial past, and an eyes-forward view of the research to come.

Dan Lopresti, Professor and Chair of computer science and engineering, was involved in many of the discussions about the design of Building C. "I'm lucky in that I get to travel around the world and see a lot of really cool buildings, and they all have aspects that are quite impressive. Building C has the flavor of buildings at Facebook and Google, and that is great for our students, but it is really unique," he says. "It's not like anywhere else you've been, and when you step inside you feel that right away."

Scheinberg's work is a prime example of the type of inquiry with broad application that the Institute hopes to foster. Scheinberg focuses on optimization, the use of sophisticated mathematical tools to generate efficient

solutions. “Optimization is extant in all engineering fields and across all data problems, which is why it is foundational and why we are good partners in the Institute. It is also at the core of most machine learning methods, which is a very important contemporary field of study,” says Scheinberg.

Scheinberg and her colleagues have received a Transdisciplinary Research in Principles of Data Science (TRIPODS) grant from the National Science Foundation, a three-year, $1.5 million award. The TRIPODS team includes Scheinberg as principal investigator, and co-investigators Frank E. Curtis and Martin Takáč, associate and assistant professors, respectively, of industrial and systems engineering, as well as Han Liu of Northwestern University and Francesco Orabona of SUNY-Stony Brook. The grant comprises three branches of study—theoretical computer science, statistics and applied mathematics—and a goal of the project is to maximize research potential by bringing together researchers from the three different communities. “You can have people in these three fields basically working on the same problem, but using different terminology, going to different conferences, and publishing in different journals,” says Curtis. “It’s a very inefficient process. We should be sharing our expertise, and that is one of the things we hope to accomplish.”

At the core of most machine learning problems is an optimization problem, Curtis explains. “If you want to get a computer to recognize a picture of a dog, one of the ways we do that is to get a bunch of images that have been classified or labeled, and give the machine enough images that it will learn what the essence of a dog is. Humans do that naturally, since we look at pictures holistically. A computer reads images zeroes and ones. There are large scale issues, but in essence, it is a computer operation where given an input, you want to generate an appropriate label. That is where optimization comes in. You want the best classifier of all this data, and

> “These problems are so large that they demand experts from all fields working together to make progress.”
>
> —Frank E. Curtis

when you say ‘best,’ you are talking about optimization and the use of mathematical processes to get that.”

Inspired by neural networks modeled on the brain, deep learning techniques are making things like self-driving cars a reality. While these techniques have been around for decades, the deep learning revolution in recent years has been made possible by today’s increased computational firepower. However, there remain enigmas embedded in deep learning tools.

“Because of the complexity of these neural networks, we don’t always know why they give the outputs that they do,” says Curtis. “The decision-making process is often opaque to developers, and in the case of a self-driving car, where incorrect decisions can be catastrophic, more transparency is required. These problems are so large that they demand experts from all fields working together to make progress.”

Miaomiao Zhang, an assistant professor of computer science and recent Data X hire, is pursuing new imaging techniques to improve the diagnosis and treatment of brain diseases. One of her current projects is extracting critical data information from caches of MRI (magnetic resonance imaging) scans to advance the understanding of brain disorders, and also make it possible to predict who might be vulnerable to neurodegenerative diseases such as Alzheimer’s.

Miaomiao Zhang and PhD student Youshan Zhang pursue research in the treatment of brain disease.

Zhang is developing machine learning algorithms that analyze the brain shape variability across large populations, hence differentiating healthy groups and those affected by neurodegenerative diseases. Brain degeneration in maladies like Alzheimer's disease can involve the loss of certain brain structures, changes in shape or shrinkage of the brain.

"The brain structure is extremely complex obviously, which makes this analysis challenging," says Zhang. "The imaging data that fully captures the details of human brains lives in a high-dimensional space, and we need to work with millions of unknown parameters simultaneously."

"Right now, the clinicians can detect a few areas of the brain associated with the disease, but it isn't clear whether these are the only structures that matter. Since there may be other affected areas, we are looking into every detail of the entire brain to determine if there are other regions that possibly relate to the disease."

Zhang's work is complicated by two major factors. First, given the intricate morphology of the brain, MRI images are difficult to analyze. Second, the high volume of data in a full MRI of the brain contains a stupefying amount of information, a computational problem that demands simplification. In addition, MRIs can contain a lot of noise; Zhang's algorithm will extract, to the degree possible, only the useful and relevant data. Moreover, since MRIs are not particularly common, Zhang's work invokes what is known as the Curse of Dimensionality.

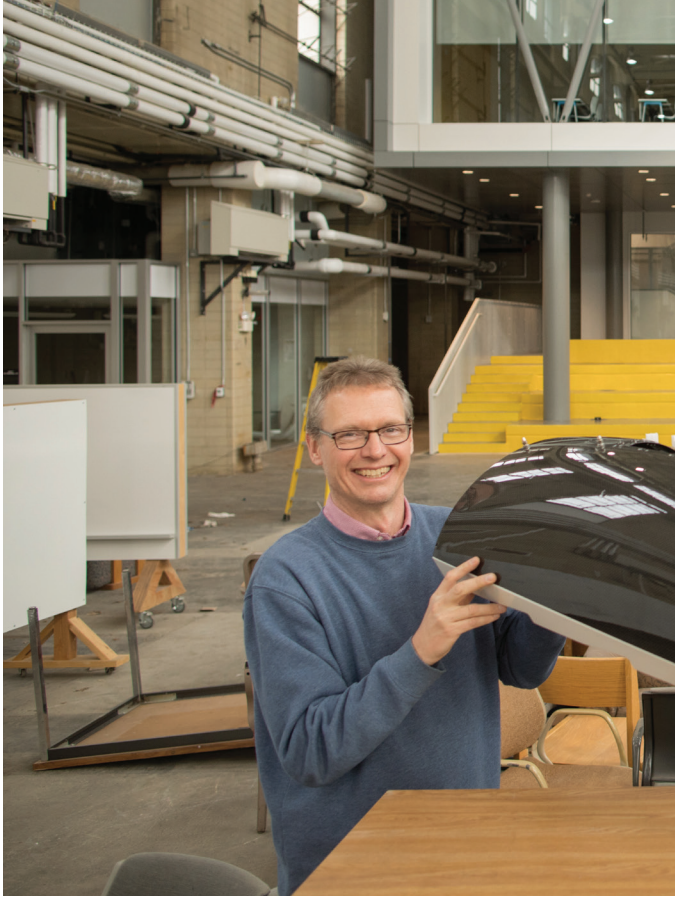
"We have very detailed MRI scans, but a relatively small population to analyze for this type of study," Zhang says. "As a result, we have to find ways to make the image analysis as precise as possible to overcome that. Our work is ongoing, but it's promising for the future."

"I think Lehigh was ahead of its time in including data science as part of the journalism and communication curriculum."

—Haiyan Jia

Zhang thinks the upcoming launch of Lehigh's College of Health will boost her work along with medical research all over campus. "The involvement of clinicians and surgeons will provide great opportunities for multidisciplinary research collaborations among computer scientists like me along with bioengineers, cognitive psychologists, and others to solve real clinical problems."

Robotics will be another vital spoke in the wheel of research at the Institute, and the soaring, 60-foot high bays will provide enough space for a small air force of drones, or for other uses yet undreamed of. John Spletzer, associate professor of computer science and head of the VADER robotics laboratory, and Joachim Grenestedt, a professor of mechanical engineering and director of Lehigh's Composites



Lab, have collaborated on groundbreaking projects using automated operations in the past, and are doing so again with watercraft.

Dubbed the Lehigh Ocean Research Craft Autonomous (LORCA), the LORCA boats are unmanned capsules about the size of a small porpoise and equally streamlined, with a top speed that a porpoise might envy. The automated craft, uploaded with map data, will hit 50 mph on a straightaway. Self-righting, the craft can be tossed into the water off a pier, and the composite shells are tough enough to withstand ocean waves. The self-driving drones could be used for surveillance, security, rescues or mapping, says Grenestedt.

"The ocean bottom can move a lot with storms. With the increase in the severity of hurricanes, it is a dynamic environment," he says. "The LORCA craft fitted with echolocation equipment could replace the tedious manual mapping process that is now used, where divers literally plunge long sticks to the sea floor to take readings."

Privacy is one of the hottest issues in data science, and a research focus of Haiyan Jia, an assistant professor of journalism and communication with the College of Arts and Sciences and a Data X hire. "I teach data journalism, digital media and privacy in my classes. Our field has had a lot of disruptions recently, and so the discussions with students are pretty lively these days," she reports. "I think Lehigh was ahead of its time in including data science as part of the journalism and communication curriculum."

The variety of human behaviors that affect privacy issues play a large role in Jia's research. "Data technology is creating so many benefits that there is no chance

Professors Joachim Grenestedt and John Spletzer display a model LORCA.

of reversing its influence, so we are left with the question of how to design a better future that minimizes risks," Jia says. "People are in an active role online; they aren't passive consumers of media. They may begin to use social media to connect with friends, but also to create their own personal identity, check up on news, or see what other people are doing, in other words, surveillance."

Understanding the matrix of motivations and behaviors is integral to finding privacy solutions, which, humans being human, is no simple task. "One of the things I focus on is the social aspect to the problem. We typically think of privacy in terms of a person, but privacy exists in a social context, and people make decisions as part of a larger community."

Another asset for Jia's work will be a digital media lab that is being installed in Building C. "My research is empirical and experimental, and would benefit greatly from a lab for this kind of research," she says. "Dan Lopresti and Jack Lule [chair of journalism and communication] are both very supportive of creating a space for this empirical, interdisciplinary work. The university has been very supportive, and we hope that the lab will be a place for faculty to conduct research, and for students to do projects as well."

All told, there could scarcely be a more auspicious moment for a new institute dedicated to collaborative work in data science. "Demand is through the roof for data analytics and computation among the students in our college," Dean Phillips reports. "And frankly, it is a functional necessity for our students."

"This societal importance of this field can't be underestimated," says Dean DeWeerth, "and it is a field where Lehigh can and will be a leader."

DATA X: REVOLUTION TO EVOLUTION

Dan Lopresti, professor and chair of Computer Science and Engineering, and the director of the Data X initiative, laid it out starkly. "Computer science positions are doubling annually, and to hire the best people, universities are also competing with Google, Facebook, and other global tech companies." For that reason, he explains, Data X was crucial in attracting top talent to Lehigh. "The initiative was extremely helpful in getting the people we wanted. We made some great faculty hires in computer science and other areas," Lopresti says.

> "Data X has been crucial in attracting top talent to Lehigh." —Dan Lopresti

In all, Data X brought seven new faculty members to Lehigh: four in computer science and engineering, and one each in journalism, marketing, and bioengineering. Haiyan Jia, an assistant professor in the department of journalism and communication, was one of the Data X hires. "When I interviewed, we talked about Lehigh finding new ways for people in different disciplines to come together around data science and more. I got really excited, and I came here because of Data X," she says. "It gave me a great opportunity to meet my colleagues and people working in areas that I might not have known about otherwise."

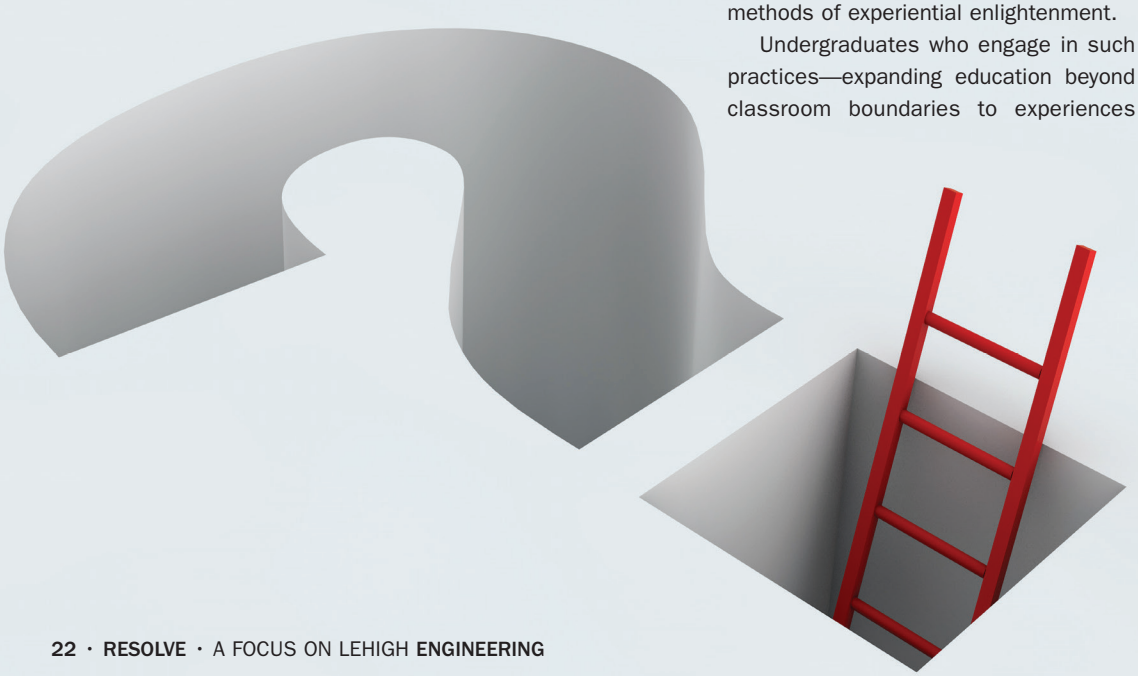
Data X is credited with sparking a dialogue across campus about what interdisciplinary research in these areas would look like. The initiative brought together researchers, sponsored symposiums, and began to satisfy the intense demand for data analytics study across a wide variety of fields. That initiative has now evolved, and the forthcoming research institutes will benefit from the paths blazed by Data X.

"Data X has been an extremely valuable initiative for Lehigh and for the Rossin College in the development of distinctive Lehigh strengths in data science and computation," says Steve DeWeerth, Professor and Dean of the Rossin College. "I-DISC will build upon that foundation to realize broad interdisciplinary research across these themes."

 BY RICHARD LALIBERTE

INQUIRY, IMPACT, AND THE VALUE OF 'DOING STUFF'

KHANJAN MEHTA PROMOTES CREATIVE INQUIRY UNIVERSITY-WIDE IN NEW VICE PROVOST POSITION



TRADITIONALLY, "MOUNTAINTOP EXPERIENCE" REFERS TO A LIFE-CHANGING MOMENT OF TRANSCENDENCE. In the airy, open spaces of Building C on Lehigh University's Mountaintop campus, the term has seemed appropriate since 2013. That's when Lehigh launched the Mountaintop Initiative, a then-experimental program in which students work across disciplines on independent projects and inquiries guided by personal passions and ideas about how they can change the world.

"The Mountaintop Initiative is a beautiful example of a program about creative inquiry and open-ended learning where students and faculty are working together on deep dives into a wide array of questions," says Khanjan Mehta, Lehigh's first Vice Provost for Creative Inquiry and director of the Mountaintop Initiative. "But it's just one snapshot of how creative inquiry comes to life."

Mehta is now directing efforts to expand on Mountaintop's successful approach to learning and weave it into education throughout the university. In his newly created position, he aims to promote and integrate creative inquiry into academics as well as high-impact learning practices, which include internships, research, global learning, entrepreneurial experiences, community-based learning and engagement, and other methods of experiential enlightenment.

Undergraduates who engage in such practices—expanding education beyond classroom boundaries to experiences that have tangible effects in the larger world—have been shown to boost their academic achievement, enhance personal development, strengthen interactions with faculty, and cultivate lifelong career success. In short, they're better prepared for what comes next, whether it's joining the workforce, pursuing advanced degrees, seeking fellowships, or chasing entrepreneurial dreams.

"When you seek a Fulbright scholarship or a job at Google, what will set you apart is not your GPA," Mehta says. "What will set you apart are all the other things you've done—the experiences you've had, the technologies you've designed, the organizations you've started. Our task is to help students and faculty develop mindsets, skillsets, and portfolios for a rapidly-changing world."

Mindset-driven learning

Based on conversations with a wide array of stakeholders, Mehta says high-impact learning practices have significant potential for growth at Lehigh. He estimates that half of students are already at least moderately engaged in some type of high-impact learning practice such as internships, research, and entrepreneurial experiences, with about 20 percent fully engaged in multiple practices with a clear emphasis on outcomes and transferable skills.

Inspiring the remainder of students to more fully embrace hands-on learning experiences depends in part on shifting attitudes away from a transactional mindset in which students emphasize graduating on time with a diploma and high GPA, and toward mindsets that emphasize approaches to life or problems. Such mindsets may include creative inquiry, ethical decision-making, global citizenship, coalition building, an entrepreneurial approach, or a systems thinking outlook.

Mindset-driven learning leads to skillsets that the World Economic Forum identifies as crucial for thriving among advanced robotics, artificial intelligence, machine learning, autonomous trans-

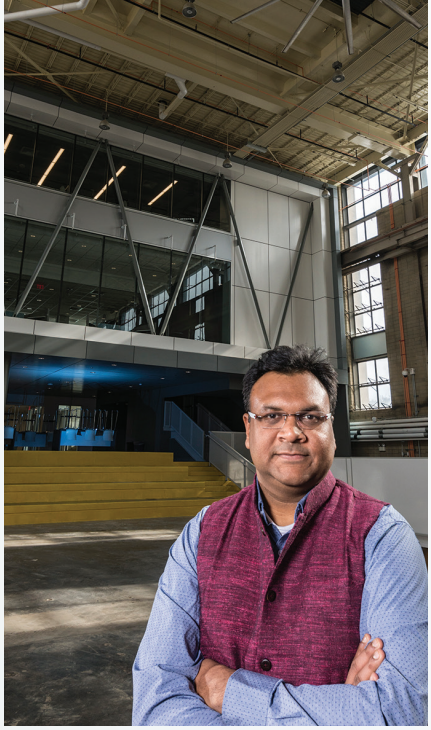
port, advanced materials, biotechnology, and genomics. Topping the WEF's skillsets list is complex problem solving.

"Our goal isn't to prepare students to be another cog in the industrial machine," Mehta says. "We're trying to help students find their purpose—who they are, what they value, what they're passionate about, how they want to change the world, and what kind of lives they want to live."

Passion and purpose comes from emotional engagement driven by hands-on experiences and inquiry-driven pedagogies, Mehta says. Experiences in turn produce tangible results—fodder for portfolios that bolster and verify a student's abilities and accomplishments. "If you've spoken at a professional conference, created and showcased a work of art at the local gallery, or your name pops up as an author on Google Scholar, that's a game changer," Mehta says. "It boosts agency and self-efficacy because you've produced something that's valued by the world, and that changes the way you see yourself. It's not a professor saying, 'Good job,' but the world saying, 'Thank you. We appreciate that.'"

Mehta steers students toward problems that have not been solved yet. "If they send me a proposal and I easily find 10 similar projects, I help them find a unique niche, context, or combination in which ideas might have more merit," he says. "My job is not to say, 'No,' but, 'Here's another way to look at it or here's another intellectual pathway worth pursuing.' Successful projects tend to work across multiple disciplines, cultures, and ways of thinking and being."

One group of students is working to design and produce inexpensive test strips that can screen for urinary tract infections in developing countries such as Sierra Leone. "Can it be done with engineering alone?" Mehta asks rhetorically. "It cannot. Students can learn in classes how to design biomedical devices or they can study community health, but this takes theory from the classroom in both disciplines and puts it into practice." The team includes a science and engineering subgroup that focuses on chemistry and product design issues. Other sub-teams focus on distribution, supply chains, customer education, regulatory compliance, and other issues.



Khanjan Mehta (left) promotes experiential learning across the university through projects like Ukweli Strips, where student inquiry is helping to improve public health initiatives in Sierra Leone.

Another team is working on advancing 3D printing of concrete, one of the most widely used building materials in modern construction. A team led by Clay Naito, a professor of civil and environmental engineering, and doctoral candidate Joseph Ingaglio, has partnered with printer manufacturer Exone and global cement production leader Buzzi Unicem to develop mix designs and ways to print concrete in different shapes and structures. The new methods require a fraction of the cement used in traditional manufacturing but are just as strong, which promises significant environmental benefits. "This would be a game changer on many levels," Mehta says. "And we are here to support our faculty and students from across campus as they engage in such ambitious interdisciplinary projects."

Sustainability also drives collaboration between three students and four faculty members who are researching new ways to recycle drywall gypsum. Most of the estimated 700,000 tons of it generated in the Eastern U.S. alone is either transformed into low-value products such as soil amendments or dumped in landfills. The team, led by Jonas Baltrusaitis, an assistant professor of chemical and biomolecular engineering, is working on methods of repurposing drywall gypsum into high-value products such as fertilizer, artificial bone substitute, or glass-ceramics for tissue engineering.

Pathways and pipelines

Beyond piloting new courses, Mehta is working to create multiple ways to start students on a journey of creative inquiry in which they're emboldened to ask questions and risk failure to get answers. For example, LearnX-MakeX-SprintX workshops enable students to explore a wide range of unfamiliar topics or use unfamiliar equipment or processes to make something tangible.

Another is a network of open and accessible creative spaces. "These might be a conference room, a studio to make a video clip, or a dirty space to work with cement or sculpture," Mehta says. "Our team is carving out spaces where we can create new things." Venues for sharing can showcase and celebrate accomplishments while inspiring others and cross-pollinating ideas.

"Knowledge is constructed," Mehta says. "Much of it is already out there. The challenge is finding it, understanding it, leveraging it, and when necessary creating it, to solve problems that matter. Creative problem solving is a contact sport, and you can't do it from afar. You need to get down into the details and do stuff."

Yinzhi Cao (above; below with Ph.D. student Song Li) explores methods for greater digital privacy and security

The digital gatekeeper

An exercise in online frugality leads to a career in digital security research

Whether you're mapping a route, buying a book, or simply checking the time, if it's on the web, Yinzhi Cao, an assistant professor of computer science and engineering, is interested in—and concerned about—how it impacts your digital privacy and security.

"People are gradually beginning to understand the importance of security, but it's still a second-tier citizen," Cao says. "Functionality, profit, convenience—they all still come first."

It was the website coupons.com that first introduced Cao to the idea of web security as a field of interest and study. "I was pursuing my Ph.D. at Northwestern at the time, and I had a colleague with a baby who asked me to help him buy diapers," he says. "The site allows you to print coupons for various goods and activities, but in this case, you could only do it twice, and then it was gone from your computer."

Cao bought his share of the diapers, but his gears kept turning. "I thought it was so interesting how the site could know that you've printed twice," he says. "I knew something was happening in the browser, and I knew that was a topic I wanted to look at more closely—web tracking."

The user side of web tracking takes many different forms, Cao says. Some—like targeted couponing and online banking authentication—are good, while others—including web advertisement personalization—are privacy violations that are mostly benefit-free.

One way Cao put his own stamp on the field is to develop a way to track users across multiple web browsers. By generating a unique fingerprint for each user with data from operating systems, graphics cards, audio hardware, and central processing units, it helps save time and protect user data across browsers like Internet Explorer, Mozilla Firefox, and Google Chrome. According to a paper Cao and his colleagues published on their work, their method can successfully fingerprint as many as 99.24 percent of users.

But tracking is merely one facet of a deeply complex and constantly changing area of study.

Cao has also developed a digital product called Safepay that aims to limit the ability of scam artists to skim someone's credit card number and use it to make fraudulent purchases.

The idea came about because the incidence of fraud was so much higher for magnetic stripe cards than it is for those with chips. However, for all the added security of chip cards, many retailers are still reluctant to adopt the technology.

"Even after the big Target breach in 2013, companies don't want to pay up front against potential loss later," Cao says. "Even with fraud responsibility shifting from the banks to the retail store and those entities, they still won't do it."

Safepay takes a novel approach to this problem by generating a unique credit card number every time you purchase. Using a mobile banking app on a smartphone, it generates this unique number and transmits it electronically through your audio jack and into an old-fashioned magnetic reader. While these devices are most closely associated with skimming problems, the fact that your credit card number would change with every purchase neutralizes this concern.

"The reluctance to change makes backward compatibility really important in the field of web security," Cao says. "Safepay is a secure alternative for those retailers that aren't ready to adopt the chip model yet."

Cao also studies security and data privacy through mobile apps. "I'm very interested in app behavior and intent," he says. "You have two apps that send your location to a third-party server. One is a map—that's fine. The other is one that sends a simple message to your friends. That's an illegitimate use. It doesn't need your location data."

Cao and his research team are trying to determine if there's a correlation in the way app developers describe their products in the digital marketplace and the product's behavior toward sensitive information. This may help app users make smarter and more informed choices about the apps they want to access their contacts, location, and other personal data.

"One project I have right now is looking at the way bugs in autonomous systems may impact people's lives," he says. With self-driving cars, he can shade a few pixels in the images of the road they're processing. "The car may need to turn left, but by introducing this bug, it'll turn right and crash into the guardrail," he says. By understanding how these bugs are interpreted and introduced, defense mechanisms can be developed.

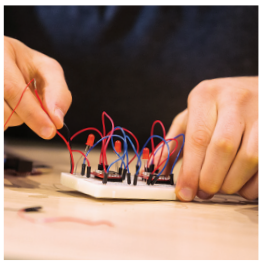
And alongside a colleague from Columbia, he also had a four-year, $1.2 million research grant funded by the National Science Foundation to explore a topic called "machine unlearning," which sought to introduce methods to permanently forget personal data into autonomous learning systems.

Cao knows privacy and security are important aspects of digital life that tend to get pushed aside for cost and other considerations. That's why he seeks to understand it from many different perspectives, always stay ahead of the curve, and create solutions that work for various customers and platforms.

It's also why he stresses security when he teaches the next generation of computer scientists and engineers.

"It's really important to me to integrate these concepts into my teaching so that students remember how important it is," he says. "I want them to keep pushing security forward."

THIS NETWORK MAKES A DIFFERENCE



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FOCUSED ON LEADERSHIP

Above all, says Judy Marks '84, President of Otis Elevator, good executives must remember that they do not lead companies—they lead people.

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