INPUT OUTPUT

The secret to rainforest conservation

could be inside this suitcase

Leverage relationships to build the master's program of tomorrow p34

What today's angel investors are looking for from university startups p44

Embracing the conundrum of generative AI in the classroom p56 **PURPOSE** There's an old adage that you get out of an endeavor whatever you put in. But just as important as the inputs and outputs is the slash between them—the planning, the infrastructure, the programs, the relationships. We hope the content within these pages helps you not only discover a little more about Duke Engineering, but also ideas and inspiration that make your own slashes a bit bigger.



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INSIDE THE PRESSURE COOKER

By MIRANDA VOLBORTH

A Duke-led team of engineers and conservationists race to beat the clock in the semifinals of a **\$10M competition** to sample rainforest biodiversity. **T THE RANGER STATION** on the edge of Singapore's Central Catchment Nature Reserve, 21 lunch orders have been separated into tidy stacks: pad thai, fried rice with pineapple and prawns, mango salad, and Vietnamese iced coffee that is sweating copiously onto the plastic folding table.

Our team trundles into the station and settles onto the rough flagstone floor with their lunches. There are botanists, birders, conservationists and engineers of every stripe with specialties as diverse as their lunch orders. Soon the sounds of plastic cutlery being unwrapped and water bottles uncapped add to the background noise of insects screaming in the forest. A coil of shiny silver ductwork shivers as a portable air conditioning unit struggles to suck the humidity from the rainforest and breathe a bit of cool relief into the packed room.

But 10 minutes' walk through the forest and down a narrow service road, mechanical engineer Juliet O'Riordan is still at our group's test site. Both lunch and relief can wait; she is searching for a suitable branch upon which to hang our team's success in the XPRIZE Rainforest competition. She's feeling immense pressure to get it right. The team has traveled across the world to be here, her teammates are depending on her, and a documentary film crew is tracking her every move.

XPRIZE Rainforest is a race to discover, understand and preserve the health of the world's richest, densest ecosystems using autonomous technology to catalogue the biodiversity found there. To win the competition's \$10 million purse, teams try to develop the quickest, most complete and most efficient means of identifying species at every level of the rainforest, canopy to floor.

\$10

OPERATIONS

In a last-ditch attempt to collect an insect from the forest, botanist Lilly Johnson prepares to send a drone trailing sticky tape into the trees. Photo: Alex Mousan Sanchez

12teams

The XPRIZE Rainforest challenge is more than an academic exercise. Tropical forests are among the most biodiverse places on earth, and they're quickly disappearing—cleared to make room for agriculture, or mines, or housing developments, or other applications judged to have more value than the standing forest. But the services that intact forests provide to society are poorly understood, hard to quantify and nearly impossible to assign monetary value to, and that makes it difficult to make the case for conservation.

But we're trying to change that here at the XPRIZE Rainforest competition semifinals in Singapore. By collecting and analyzing data about the species found here, we hope to offer new insights into the complicated, interdependent relationships that exist in the rainforest and the wealth of benefits they provide. To advance to the finals, we have to demonstrate our intent and our ability to generate these insights—and that depends wholly on our successful collection of sound recording, photographs, and biological data collected from the rainforest.



We have only 24 hours to collect data, and 48 hours to transform the data into insights.

WE'RE COMPETING against 12 other teams from around the world. The XPRIZE judges tell us that the approaches are wildly different across the semifinalist pool, but won't give details; we have, however, heard rumors of robotic dogs that fetch images of native foliage and of new techniques for collecting environmental DNA from the forest floor.

Our team, the Blue Devil Forest Divers, is led by Duke University Associate Professor of Electrical and Computer



Engineering Martin Brooke and Duke Professor of Conservation Ecology Stuart Pimm and takes a dronebased data collection approach. We've descended upon Singapore's Windsor Nature Park with a fleet of 22 drones ranging in size from an eastern box turtle to a giant tortoise.

Most of them are ANAFIS, small vehicles manufactured by the Parrot company, which are packed into hard-shell suitcases the color of nonpareil mint drops. In two table-sized crates, though, wrapped like mummies in swathes of stiff brown hex paper, are the components of the large drones that we call the Mother and the Relay. These drones are unique, both to the competition and to rainforest conservation. They've been designed and built from scratch by Duke University students enrolled in Brooke's Ocean Engineering and Rainforest Engineering classes, each new wave of students squeezing a bit more utility and performance out of the drones every semester.

Mother is a hybrid drone that uses a gasoline– powered engine to extend the range that her battery affords. She's essentially a school bus, ferrying the little battery–powered drones deep into the forest, much farther than they could fly on their own. The other large drone—the Relay—is a hybrid–fueled communications way station that hovers, tethered, above the canopy to



listen for messages from Mother and communicate them to researchers on the ground.

The scheme allows our team to efficiently canvass more of the forest than if we were depending only upon battery power. In the semifinals, the test plot is within throwing distance of a service road, so the large drones aren't even necessarythe small drones can reach the center of the plot under their own power. But this round of competition is an excellent opportunity for our team to learn how to ship, reassemble and safely fuel the large drones in addition to flying them.

3D-printed insect traps were engineered to slide on and off small **drones, so they can** be left to hang in the rainforest canopy. **Photos this page:** Alex Mousan Sanchez



Mechanical engineer Juliet O'Riordan assembles sound and insect traps, which will deliver audio recordings and DNA to the team when retrieved.

22drones

The data collection period begins tomorrow morning.

SINGAPORE is a densely populated city-state, and its airspace is strictly controlled. The large drones are therefore subject to extensive airworthiness checks: the ability to display signal strength and failure warnings for each fuel source, to give flight telemetry, to perform a controlled four-minute flight with changing orientation, to communicate an uninterrupted video screen and to land within a designated area.

The engineers assigned to the large drones soldier through dozens of attempts and recalibrations as the sun rises higher and the open field begins to stream. Mother's steady chirps are punctuated by the noise of two roosters fighting atop a wall that separates the test field from an adjacent housing block.

Just when it seems the overheated students might give up, Mother suddenly pops into the sky like a



kernel of corn. She climbs to around 20 feet and hovers like a dragonfly above the cheering team.

But the sweet victory is short-lived. Mother falls from the sky on her next flight, coming apart neatly when she hits the ground as she was designed to do. Her motor and electronics can be salvaged this way, and her frame rebuilt back home.

The engineers attribute the crash to the PID tuning—the software parameters that affect how the flight controller responds to commands—and all agree it could have been corrected with a bit more practice. The wind, or even the weight of the additional zip ties securing the motor to the frame, might have thrown the drone out of balance.

But a thorough critique will have to wait.

It's noon, and the clock is now ticking.

THE LARGE DRONE PILOTS, relieved of their vehicles, start registering flights on the small drones. A trio of University of Wisconsin-Madison botanists, led by orchid expert Stephanie Pimm Lyon, hovers over the pilots' shoulders, directing them to areas of possible interest to photograph. Images of leaves and vines begin pouring in almost immediately, to their gratification. But other groups are waiting on data from two yet-to-be-deployed traps: a recorder that captures birdsong and a sticky insect lure.

We have two Tupperware containers full of insect bait. One contains slumping chunks of mango and banana whose edges are slowly dissolving into soup. Another is packed with balls of raw pork that have taken on a greenish cast and smell like fish guts. Liquid as dark as swamp water pools at the bottom.





Allison Goehringer and Achilles Dabrowski calibrate the Mother drone, above.

These slurries will be irresistible to flies and beetles, sending them careening into the sticky sides of the traps.

Duke biomedical engineering lab administrator Maggie Gatongi and J.A. Jones Distinguished Professor of Electrical and Computer Engineering Nan Jokerst have set up a mobile DNA barcoding lab in the ranger station. They wait with small, high-powered microscopes to photograph the stuck insects—the first step of 14 in their protocol, which will end in a foolproof species ID. In their lab coats and sterile gloves, they double-check and triple-check their procedures as they wait for the first batch of captured insects to arrive.

Which brings us back to O'Riordan's hunt for the perfect branch, and the corresponding challenge: there don't seem to be any good branches, let alone perfect ones, from which to hang an insect trap.

She and her co-pilot, ECE alum Alex Xu, send numerous drones scouting through the test plot. The vegetation is thick and weedy, and the long, whip-thin branches frequently tangle in the drones' propellors and send them tumbling to the forest floor. They've been lucky so far—if they crashed instead into a treetop or other inaccessible area, the drone couldn't be retrieved until the end of the competition. In that scenario, the team would lose not only their drone, but also the trap or data it was carrying as well.



The sun sets at 7:10 PM.

BY THE TIME DARKNESS FALLS—almost as quickly as a switch flipping, here near the Earth's equator—the pilots have captured 238 images of the rainforest's plant species. One trap, a bioacoustics recorder, is now hanging on a thick vine, where it will remain overnight to eavesdrop on the early-morning conversations of the waking birds.

Despite this success, pressure is still building. "It is essential that in the morning we place an insect trap inside the valid area," Brooke urges in a message to the group via WhatsApp. "We'll take it steady and make it happen," Xu responds in the thread, to a chorus of heart emojis that pop up from his teammates.

A group of pilots return to the test site at 4 AM after a quick nap. They outfit the drones with thermal cameras, hoping to spot the warm auras of macaques or wild boar through the cool blue canopy—a strategy that had worked well both in Durham and in the jungle of La Selva Biological Station in Costa Rica, where the team tested its approach last summer.

The sun rises on a still rainforest, illuminating only plants and foliage.

It's 9 AM, and only three hours are left in the collection period.

BROOKE URGES O'Riordan to retrieve the sound recorder, but she and Xu are still scanning endlessly for perforations in the dense foliage, searching for a place to safely drop an insect trap. We only need one to prove that our DNA barcoding technique works.

At this critical moment, a safety officer makes an unwelcome announcement: there's a Category 1 lightning storm approaching, and all flights are grounded until the threat passes. Only six people may remain beneath the tent, so the rest of us scurry up the hill to the ranger station, through the sweltering jungle.

Singapore's Central Catchment Reserve is essentially an inner-city woodlot. It's different from mature rainforests, where old emergent trees compose the forest's crown. Below, the canopy is so dense that it creates shade and a dark, sparse forest floor. Here in Singapore, emergent trees are few and far between, and the canopy below allows much more sunlight

Alexandra Rivera, Alex Xu and Juliet O'Riordan are surrounded by a documentary film crew as they fly a drone into the forest, far right. Photos this page: Alex Mousan Sanchez





to filter down to the forest floor, creating conditions where small plants and shrubs thrive.

In the mature rainforest, there were innumerable unobstructed branches for O'Riordan to aim for. In Singapore, there are none.

The lightning warning is lifted just before 11 AM.

111. 10



One hour remains in which to collect and retrieve data from the rainforest.

THE DRONE PILOTS in the ranger station sprint back toward the test site, where O'Riordan and Xu are already initiating their flight plan. Botanist Lilly Johnson is just behind them, carrying a length of red braid made from strips of a plastic biohazard bag.

No one spares the time to ask questions about this makeshift lanyard; every eye is on O'Riordan as she assembles another insect trap beneath the red tent.

One of the most remarkable things about this team is the latitude that Brooke and Pimm have allowed the students and recent graduates who comprise the team to plan for themselves and make their own decisions. The faculty members provide vision and they provide resources: expert entomologists, large trucks, drone transponders and controllers, portable DNA sequencers, mountains of Malaysian takeout. But apart from assisting with one particularly tricky bit of soldering, Brooke has, until this morning, remained hands-off. It speaks to the pressure the entire team is under that this dynamic has now changed.

"Try to recover the sound recorder," Brooke urges her.

As the two confer, Johnson brings a small drone to the table. From a sheet of yellow fly paper, she cuts long strips with the speed and precision of a sous chef and affixes them to the drone with the braided lanyard and runs with it to the top of the test site.

With just 36 minutes left in the collection period, our pilots have split into two factions, each frantically trying to engineer a win for the entire team.

At the top of the hill, one group is making a last-ditch attempt to collect an insect sample by dragging a long loop of fly paper through the canopy. At the bottom of the hill, Xu stands in the middle of the narrow service road, lofting a drone above his head, searching for the strongest signal to support O'Riordan's recovery efforts.

Midflight, O'Riordan and Xu lose their signal and must abandon the attempt. It's unclear whether the competing flight at the top of the hill is interfering.

Brooke charges up the hill to intervene, and O'Riordan uses the distraction to quietly launch an attempt to retrieve the sound recorder. She knows the spot she wants and aligns herself to the opening she sees; her drone buzzes alongside her. It takes only a minute for the Parrot to reach the sound recorder, and it snaps

8



Small drones like the one pictured above can launch and land from honeycombed platforms affixed to the team's large custom drones. Left, pictured left to right: Juliet O'Riordan, Rebecca Schmitt, Lilly Johnson, Alison Korn and Allison Taub register a flight. Photos this page: Alex Mousan Sanchez

up the device with a strong magnet and turns back toward the service road, carrying its payload.

Everyone has pivoted their attention back to O'Riordan—our whole team, the safety officers, the XPRIZE staffers and the film crew with their cameras rolling—so everyone hears when the drone starts to go down, making a sound like a weed whacker as it becomes entangled in the undergrowth. The drone and the recorder fall so close to the road that we can see the vehicle's propellers still fighting valiantly to turn from amidst a nest of vines. Its lights blink orange in a silent SOS.



22 minutes remain on the clock.

WE HAVE NO INSECTS. We have no sound data. O'Riordan sinks briefly to the ground, folding in on herself like a paper crane.

The drone is almost close enough to touch and the urge to simply pluck it from the brush is strong, but the rules of the competition prevent human beings from entering the plot.

One student commandeers the communications team's tripod and telescopes its legs to their longest. Another finds a fallen branch taller than he is. Working in tandem, they use the two implements like giant chopsticks and reach for the sound trap. Their jostling separates the drone from the recorder and the precious data slips perilously close to the forest floor.

There is absolutely no way this will work.

But they somehow flip the device out of the thicket and onto the dirt between the road and the brush, where it's fair game.

A doctoral student in Pimm's group snatches the sound recorder and scampers away to download the data, quick as a macaque with a contraband protein bar.

The flypaper, meanwhile, is dotted with tiny specks of dark matter that appear to be nothing, but an XPRIZE staffer documents the time and location of the collection anyway, just

> as the clock runs out. Jokerst and Gatongi examine the loop of sticky tape under the compact microscopes they've brought from Duke, methodically zooming in on one amorphous blob after another.

Then, there it is, swimming up through the microscope's light and into sharp focus against the yellow tape: a segmented abdomen and a pair of translucent wings.

Alexandra Rivera assembles a large drone at Garuda Robotics in Singapore. Photo: Miranda Volborth







00:00

Maggie Gatongi (top left) and Nan Jokerst (top right) use photos to document a captured insect before preparing it for DNA barcoding. Photos by Alex Mousan Sanchez. Below: Team leader Martin Brooke evaluates a drone's camera as Will Reynolds prepares to take an airworthiness test. Photo: Miranda Volborth

Insights

THE TEAM'S ALLOTTED TIME at the ranger station has ended, but the National University of Singapore has offered space in one of its wet labs for the competitors to perform DNA and eDNA analysis, so Gatongi and Jokerst shift into high gear to prepare our single sample for processing.

The collection period ended at full boil, but Gatongi is an island of cool. In the NUS wet lab, she is perfectly at home; she has taught hundreds of students to perform the polymerase chain reaction, or PCR, protocol that she now initiates.

She and Jokerst turn their results over to a recent biomedical engineering alum at 1 AM. It takes another three hours for him to run the DNA sequence on a base caller and name the insect: *Scirtothrips dorsalus*, a species of invasive thrip. The DNA ID confirms the visual one made by renowned entomologist Roger Kitching.

To the terabytes of data collected by the team, this small, precious bit of information is added. It's proof that the DNA barcoding technique works and could be applied on a bigger scale in the finals of the competition.

Brooke emails the team's final report to XPRIZE. There are 63 unique taxa the team identified in the competition using photo, audio and DNA identification methods. The species richness of the rainforest plot has been described, and heat tree diagrams show how each individual species fits into the whole. From the chaos of the competition, an ordered snapshot of the rainforest's biodiversity has emerged.



HE TEAM DISPERSES to all corners of the globe—to South Africa, to study the fragmentation of elephant populations; to new jobs in the forestry service and existing ones at Microsoft; to internships at Apple; to deserved vacations. But they still steal time to pore over the footage of Mother's crash, looking for clues to inform her next incarnation and make her more resilient, and to troll iNaturalist after hours to see how the other teams fared at their plant identification task and to work out the odds of our team making it to the finals.

Several weeks later, at the International Congress for Conservation Biology in Kigali, Rwanda, the XPRIZE Foundation announces the finalists. The six teams with the highest species count advance. The Blue Devil Forest Divers are not among them.

The shock of the news is like being blanched in an ice water bath. But the team rallies to thank one another and prepares to pass the baton. Only four undergraduate students on the team will return to Duke in the fall.

Brooke has competed in five different XPRIZE competitions now and says that managing the constant turnover is the biggest challenge—but Duke's participation isn't driven by winning, it's driven by the university's educational mission. More than 200 students have contributed their time and effort to this project, and many more will have the opportunity in the coming years. They learn and apply technical skills, but they also learn to manage complex logistical challenges, team dynamics and their own expectations.

Brooke is teaching Ocean Engineering in the fall and students in the class will be rebuilding the large drones and outfitting them for longrange ocean device delivery. Brooke imagines that there might be an ocean-focused XPRIZE competition in the near future and if there is, Duke will take a swing at it.

"We did everything we set out to do," says Brooke. "We had great opportunities for students in classes to work on authentic projects, and we got to test many of our technologies in rainforest environments. Things went better than I had hoped for, in many ways. And we had an absolute blast." **1/0**



BLUE DEVIL FOREST DIVERS

Martin Brooke, Associate Professor of Electrical and Computer Engineering (ECE) Stuart Pimm, Doris Duke Professor of Conservation Ecology, Nicholas School of the Environment (NSoE) Jacqueline Fahrenholz-MEM'22, MF'22, NSoE Achilles Dabrowski-ECE/CS'21 Rebecca Schmitt-ME/ Mathematics'21, M.S. ME'22 Maggie Gatongi-Senior Lab Administrator, Biomedical Engineering (BME) Allison Goehringer-ME'24 Christopher Hall-CS'23 Ryan Huang-PhD'19 NSoE Nan Jokerst–J. A. Jones **Distinguished Professor of ECE** Alison Korn-ME'24 Allison Taub-ME'24 Juliet O'Riordan-ME'21, M.S. MEMS'22 Allen Parayil-ME'24 William Reynolds-CS/ Environmental Science '22 Alex Xu-ECE/CS'22 Alexandra Rivera-M.S. MEMS'23 Sigi Liang-PhD '25 NSoE Tim Ho-BME/CS'23 Miranda Volborth-Pratt **Communications & Marketing** Alexandra Mousan Sanchez-Pratt **Communications & Marketing**

Roger Kitching–Emeritus Professor, Animal Ecology, Griffith University

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Akiva Lyon

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Could Quantum Give us the Generative Al We're Looking for?

Quantum computing and artificial intelligence (AI) might seem as distant from each other as New York and Los Angeles. But according to Duke Quantum Center (DQC) director **Chris Monroe**, the two subjects are practically next-door neighbors.

By MIRANDA VOLBORTH

"QUANTUM AND AI are often spoken about together, and it makes sense because quantum will accelerate the next generation of AI," said Monroe, the Gilhuly Family Presidential Distinguished Professor at Duke University with appointments in electrical and computer engineering and physics. "Even ChatGPT, the current poster child for state-of-theart AI technology, is currently limited in its ability because computers can't make correlations among a trillion objects. There's just not enough memory in a computer to do that."

Monroe is speaking, of course, about traditional bit-leveraging computers that make yes/no evaluations. Quantum systems of the type that Monroe and his colleagues at the DQC are building have the potential for infinitely more computing power—which could theoretically translate to infinitely more capable AI tools.

"Machine learning and AI is so interesting because it's highly empirical," said Jungsang Kim, the Schiciano Family **Distinguished Professor of Electrical** and Computer Engineering at Duke who, with Monroe, co-founded the quantum computing company IonQ, which caters to industry collaborators. "We throw a lot of data and models and computational power at the problem, but we have limited insight about how and why the AI technology works. Nevertheless, it's available for use and has already had huge impact. In the machine learning and AI space, the really interesting question is, 'are there opportunities for quantum to really make a difference?""

Large language models (LLMs) are certainly adept at summarizing mountains of data or presenting highly stylized text. But at this juncture, LLMs cannot keep up with specialized knowledge—according

OPERATIONS



Illustrations of Romeo and Juliet, rendered by AI platform Dall-E in the styles of Basquiat, Lichtenstein, Fairey and Kooning.

> to ChatGPT, its last update on advances in quantum computing was made in September 2021—nor can it synthesize ideas or generate new ones.

Here's a quick example. Currently, if a user queries ChatGPT about why Juliet is likened to the sun in the balcony scene of Romeo and Juliet, the tool returns this response:

"By comparing Juliet to the sun, Romeo is conveying several meanings:

- Radiance and Beauty: The sun is often associated with light and beauty. Romeo is expressing how Juliet's presence illuminates his world and fills it with beauty.
- Warmth and Comfort: The sun provides warmth and comfort. In a similar way, Juliet's love and affection bring warmth and comfort to Romeo's heart.
- **Center of Attention:** The sun is the center of the universe in the geocentric model, around which

everything revolves. In this context, Romeo is emphasizing how Juliet is the center of his universe, and his world revolves around her.

- Vitality and Life: The sun is essential for life on Earth. Romeo may be suggesting that Juliet is his source of life and vitality, without whom he would be lost.
- **Unattainable Distance:** Just as the sun is distant and unattainable, Juliet is seemingly unattainable due to the feud between their families. This adds to the dramatic tension of their love."

It's quite a satisfactory summary of what is surely a vast body of literature on the subject. When invited to write a new simile comparing Juliet to a different planetary body, however, the LLM's shortcomings are made clear in its response: "Juliet's presence in my life is like a distant planet, captivating and mysterious, with an orbit that pulls at the very fabric of my being."

The problem with that AI-generated simile—



"In the machine learning and AI space, the really interesting question is, 'are there opportunities for quantum to really make a difference?" – JUNGSANG KIM



aside from it reading more like "The Notebook" than "Romeo and Juliet"—is that an orbit does not exert any pull, a fact that ChatGPT acknowledged when pressed.

Language models like ChatGPT are probabilistic, meaning that they generate strings of words based on the probability of which word is likely to sequentially follow the next—which likely resulted in the incorrect language in the example above. Given the vast number of words and configurations in which they are arranged and rearranged to form sentences, the internal mathematical models that underpin them, and the amount of data required to train them, are enormous. The myriad correlations that the models must make are difficult to capture with classical computers, but there's a dawning realization that quantum computers' superior ability to recognize patterns and predict multiple simultaneous outcomes could give AI models a leg up.

"If you use quantum models to capture the structure of data like images, they're very effective—even right now, with the small quantum computers we have," said Kim.

Generative AI comprises just a small sliver of machine learning applications, and there are innumerable opportunities for businesses to automate tasks or make them more efficient with machine learning—semiconductor chip design is one example. It's one reason why quantum initiatives are still proliferating around the world. But a significant challenge for these new players is leveling up on a field that's been dominated for decades by a few key teams.

The U.S. has invested significantly in quantum computing research and development since the mid-1990s, and the United Kingdom and Singapore quickly followed suit. Now, a host of other countries are standing up their own quantum initiatives—but with the early adopters so far ahead on the research and development front, newcomers are taking alternate routes.

"In quantum, there are makers and takers," said Kim. "Makers develop technologies and build devices. The U.S. has a lot of makers, from startups to large companies building quantum computing devices, because we developed the technology here. Then there are takers—these people are not necessarily interested in making quantum computers themselves but want to figure out how to use the makers' technology to benefit their businesses. They have the opportunity to win through partnerships, and they should not be shy OPERATIONS





about leveraging advances made by industry in other countries."

"Some people worry that quantum computing technology is overhyped, that we're headed for a 'Valley of Death,' where the vertical axis is the amount of investment or interest in the technology and the horizontal axis is time," said Monroe. "It's also called the hype cycle. When you get to the very top and the technology is still years away from being realized, people become disillusioned."

The National Quantum Initiative, which was launched in 2018, endowed the National Science Foundation, the Department of Energy, and the National Institute of Standards and Technology with new programs to advance quantum computing, of which Duke has captured a



"If you use quantum models to capture the structure of data like images, they're very effective—even right now, with the small quantum computers we have."-JUNGSANG KIM



significant slice. And IARPA made a \$31 million investment in the partnership among Monroe, Kim and Michael J. Fitzpatrick Distinguished Professor of Electrical and Computer Engineering Ken Brown; the funding allowed the trio to procure the multichannel optical modulators that catch and steer atoms, making the forward leaps and bounds of their ion trapping research possible.

Now, Congress is considering the National Quantum Initiative for renewal. Kim is currently serving as a special advisor to Korea, which is laying the foundations of its own \$2.5 billion quantum computing program. Brazil, Spain, South Africa and the UK all created new quantum computing initiatives last year. If these investments are any indicator, interest in the technology hasn't reached its peak. But you don't have to take Kim's and Monroe's word for it; just ask ChatGPT itself.

"Quantum computing has the potential to bring about significant advancements in various fields, including machine learning and natural language processing, which could potentially improve models like myself. However, the extent to which quantum computing will directly impact my capabilities depends on the specific developments that occur in the field. As the field progresses and challenges are addressed, we may see more concrete and significant improvements in AI and other technologies." **I/O**



Sometimes in Microbial Life, Size Matters

The multi-institutional PreMiEr Engineering Research Center will rely on three life-sized test beds to examine how microbial communities affect human health in the places people live, work and play.

👕 By KEN KINGERY

One of the most difficult environments to keep unwanted microbes from making people sick can be found in our own bathrooms, which will be one of the first targets of investigation by the PreMiEr Engineering Research Center. Photo courtesy Duke Hospital. hen Duke University Hospital fully opened its 11-floor, 350-bed Central Tower to patients in late 2021, it represented a lot of things to a lot of people. For a hospital system still dealing with the peak waves of the pandemic, it meant more space and newer facilities to meet the unending demand. For Duke Children's Hospital, it meant an upgraded home complete with larger rooms, transitional furniture, activity rooms and family zones. For the construction company Skanska, it meant the culmination of nearly five years' worth of work, completing the \$265 million project on time.

The tower came with all the bells and whistles. Rooms that were, on average, twice as big as other buildings in the complex. The surgical facilities featured the latest advances in technology to ensure a comfortable setting for care. The entrance and lobby area featured high ceilings, large waiting areas and a shiny new Starbucks.

Deverick Anderson couldn't wait to see the bacteria move in. "With the opening of Duke Central Tower, our group saw an opportunity to characterize how bacterial communities change over time within the plumbing of the sinks, starting with a fresh slate," P-traps keep a small amount of water within the pipeline to stop gas from flowing back through the system. But they also create a perfect environment for microbial communities to thrive.

Modeling Large Intestines

Another smaller-scale test bed resides in the laboratory of Lawrence David, associate professor of molecular genetics and microbiology at Duke. His setup features a set of eight replicate bioreactors; essentially one-liter fermentation vessels that allow researchers to replicate conditions and microbial communities found in the human large intestine. In this test bed, researchers can explore questions such as how bacteria might live or interact with bacteria typically found in the human gut, what sorts of pertubations in the human gut environment lead to changes in the microbiome, and what levels of bacterial exposure are required for different species to successfully colonize within the human gut.



said Anderson, professor of infectious diseases at the Duke University School of Medicine. "Within a year, almost 100% of them were contaminated with antibiotic-resistant pathogens.

"There's a growing focus in the field on having water management plans in healthcare settings to mitigate these health threats. Not to make the bathrooms sterile, obviously, because that would be impossible. But trying to understand how to decrease or mitigate potential problems for patients."

That, in a nutshell, is the overarching goal of the Engineering Research Center for Precision Microbiome Engineering, or PreMiEr for short. Funded by up to \$52 million from the National Science Foundation (NSF), PreMiEr aims to develop diagnostic tools and engineering approaches that promote building designs for preventing the colonization of harmful bacteria, fungi or viruses, while encouraging beneficial microorganisms.

The hospital rooms in Duke Central Tower—and other facilities in the complex, featuring hardware and technology from different decades stretching back to the early 80s—are just one of three life-sized "test beds" that the research consortium will use to work toward this ambitious goal. A second test bed also resides on Duke's campus in the form of a home originally built for faculty members back in the 1920s. And the third is both more expansive and varied than either of those found in North Carolina; a consortium of different buildings, both professional and residential, located throughout La Paz, Bolivia.

Together, along with smaller, tightly controlled experimental settings, the three real-world test beds offer researchers complementary opportunities. On various scales and with various controls, researchers will look to explore how microbes—both harmful and beneficial—are introduced to, expand through, interact across and share space with their human cohabitants.

"Even though we're engineers, we usually work on widgets in the lab and don't get opportunities to actually build at scale," said Claudia Gunsch, professor of civil and environmental engineering at Duke and director of PreMiEr. "But one of the requirements of NSF's Engineering Research Center system is to think about how findings will actually be deployed at scale, which forced us to think about how we'd take our work outside of the lab and push the envelope."

Controlling for P(traps) in Bathrooms

When Anderson first began his career studying the spread of infectious diseases at Duke, the field was mostly focused on disinfecting surfaces and instruments throughout a hospital. And that makes sense. COVID taught us how easy it is for someone to inadvertently touch a contaminated desktop and then infect themselves by picking their nose. Extend that to a hospital setting where patients are constantly leaving pathogens behind on the surfaces and items in their rooms and in the hallways, and it's easy to understand why that would be the priority.

But about a decade ago, a series of unfortunate events at Duke University Hospital put Anderson on to a slightly different scent. Not long after the 611,000-square-foot Duke Medicine Pavilion opened in 2013, doctors and staff were faced with a quickly spreading instance of *Mycobacterium abscessus*—a group of rapidly growing, multidrug-resistant bacteria that are responsible for a wide spectrum of skin and soft tissue diseases, central nervous system infections, and ocular and other infections.

After getting the issue under control and running downstream investigations, it was believed that the source of the problem was the building's plumbing. More specifically, the P-traps found almost ubiquitously beneath sinks around the world.

P-traps are the little squiggly bit of piping underneath sinks that dip down into a "U" shape





Replicating Conditions

Along with the three large test beds being used in PreMiEr is a set of smaller test beds found in the laboratory of Barbara Turpin, professor of environmental sciences and engineering at UNC-Chapel Hill. Her lab features a continuously stirred tank reactor that can generate aerosols under various environmental conditions like relative humidity and mixes of gases for long periods of times to investigate how microbes behave when aerosolized. Her lab also features long flow reactors where researchers can insert surfaces from the real world, like pieces of walls or windows that have been soiled authentically, to see how they interact with the air and the environment. A third setup features a cylindrical reactor that can introduce variables like ultraviolet light or oxidizing radicals. Between the three, her lab can study processes in a controlled setting to understand how microbes behave in simpler environments than a complex test bed.

This former faculty housing built in the early 1900s will serve as a life-sized test bed for studying how microbes colonize our living spaces. Photo: Alex Mousan Sanchez

before leveling out and connecting to the wall. The curve ensures that a little bit of water remains behind in the bend after the water has stopped flowing to prevent any gases from the downstream sewer lines and piping from coming back up.

That little bit of water, however, also creates an incredibly attractive environment for bacteria to grow.

"Sinks in hospitals are used for more than just handwashing, and the P-trap components especially are prone to supporting microbial populations that we have no good way of eliminating," Anderson said. "Even if you remove the sinks and wall plumbing, the biofilm can march back in. It takes time, but it does come back. It's really difficult to irradicate."

The incident started Anderson down a path of taking plumbing more seriously as a potential source of patient infection. Along with additional data and observations over the following two years to show the issue was not a singular event, the experience helped push plumbing issues to the same level as surface contamination in Anderson's eyes and others throughout his field.

It's a continuing issue that has yet to be solved in any meaningful way, other than to continuously pour disinfecting solutions through the systems. For several years, Anderson has been working with a biomedical engineer at Duke, Lingchong You, to see if they could introduce different, more beneficial species of bacteria into the equation to help keep the pathogens at bay. They are, in short, searching for a sort of P-trap probiotic.

But P-traps exist in most households, businesses and buildings in general throughout the world. Their potential to spread disease is not limited to hospital settings. Given the work that Anderson has put in on the topic, and that the second Duke-based test bed also has plenty of P-traps, it makes for a natural first topic of study for the new center.

Over the coming year, Gunsch plans to begin conducting experiments in the bathroom sinks of the old faculty housing. While the 100-year-old house isn't a perfectly controlled environment, it has far fewer variables than the consistently occupied and busy hospital rooms Anderson tracks.

Their first experiments will try to get a better understanding of how the microbes aerosolize from the sink's hardware into the surrounding indoor environment. Because nobody is actually living there, the researchers can simulate people washing their hands or brushing their teeth by adding mock microbial communities and simulating the activities people living in a space go through on a daily basis. Over time, the team can introduce variables, like different kinds of personal products and bathroom hardware, to see what effect those might have on the microbes and how they grow and spread.

On a smaller scale, the center will turn to another of its team members for more tightly controlled experiments. Barbara Turpin, professor of environmental sciences and engineering at the University of North Carolina at Chapel Hill (UNC-Chapel Hill), runs a laboratory with arm-sized cylinders that tightly control and measure how various liquids, microbes and chemicals mix together and aerosolize into potential human exposures. (More info in short sidebar.)

In the longer term, Gunsch hopes she can eventually turn the former faculty housing into an experimental system approaching that level of control; something similar to how the National Institute of Standards and Technology has a fully sealed, fully controlled, roomsized laboratory for measuring aerosols.

"In the long term, we hope we can get to the point where we can do experiments where we look at when people come into a space, how those individuals "In the long term, we hope we can get to the point where we can do experiments where we look at when people come into a space, how those individuals alter the microbiome in those spaces, how quickly that happens, and what the best practices are for minimizing the spread of particular organisms that we don't want around."-claudia gunsch

alter the microbiome in those spaces, how quickly that happens, and what the best practices are for minimizing the spread of particular organisms that we don't want around," Gunsch said.

The Other End of the Control Spectrum

While the testbeds at Duke Hospital and Duke University represent one side of the control spectrum, the buildings and structures in Bolivia occupy the complete opposite. Hospital rooms have tight air filtration requirements and specialized HVAC units, while occupants and staff are constantly cleaning and sanitizing everything within sight. While the campus test bed may be an aging home, the number of people visiting, the products being used and the air conditioning systems can still be accounted for.

None of those situations apply to Bolivia.

"The big idea around the test bed in Bolivia is to understand environments that are very different from those in the U.S. and, indeed, in the rest of PreMiEr," said Joe Brown, associate professor of environmental sciences and engineering at UNC-Chapel Hill. "It's an opportunity to study some aspects of this work in a place where the stakes are lot higher because there are more pathogens and a greater threat of emergence."

For starters, Brown explains, buildings generally



don't have central HVAC, so they're more open to the outside. Rural areas have larger influences from animals, both wild and domestic. There are also many places that have a relatively high pathogenic burden compared to the U.S., leading to a much higher potential for antibiotic resistance to grow and spread.

Brown already has a strong track record in the area, having worked on NSF-sponsored projects for the past seven years along with local partners in Universidad Católica Boliviana and Universidad Mayor de San Andrés. Through those collaborations, he's been taking microbial samples across different types of buildings—urban versus rural, households versus institutional—to begin the process of generating hypotheses to refine the questions PreMiEr wants to ask going forward.

To understand why this baseline of inquiry is needed, it's useful to look at some of Brown's work that was published in 2021. It showed that microbes that cause many waste-borne diseases with the potential to spread into the surrounding environment are present in air particles around areas that have open sewers, which are prevalent in many Bolivian cities.

For example, he found that 25% of samples from La Paz were positive for culturable *E. coli*, indicating that at least some may have been capable of infecting people when sampled. In contrast, when conducting similar studies in Atlanta, which is comparable in population density, no pathogens found in aerosol particles were accompanied by culturable *E. coli*.

These differences, according to Gunsch, are critical to PreMiEr's mission for several reasons. For one, the researchers recognize that different places in the world







Joe Brown leads a group of students through the streets and buildings of La Paz, Bolivia. Conducting microbial community experiments in a wide range of settings will allow PreMiEr to build better models and explore differences between geographic locations and cultures. Photos courtesy Joe Brown.

face different challenges than those in the United States, and they want to produce results that will benefit people across the entire world. But the higher rate of pathogenic exposure is also critical to what PreMiEr is trying to accomplish.

"It's difficult to create computational models of how aerosolized pathogens travel into and through our buildings and homes because the numbers in the United States are so small," Gunsch said. "Working in Bolivia can actually help us develop a better model because of their higher burdens. We can then test those models in our test bed house with its lower burden to see if they still hold." That computational work should, in theory, then have a large impact on the recommendations that PreMiEr is able to generate for anybody living anywhere in any situation.

"We're focused on ensuring we translate this fundamental research into practical applications for how we design buildings, that's the central point of the center," said Brown. "While some of the work is a bit theoretical to start, we're engineers, and we want to affect the real world. These test beds are our greatest tools to make sure we achieve the most impact that we possibly can." **I/O**



It's Easier **Being** Green

How a collaboration spanning departments and institutions brought clarity to the mystery of **glassfrog** transparency.

By MICHAELA MARTINEZ

A sleeping male glassfrog (left) and a sleeping female glassfrog (right). An unlikely collaboration between biologists and biomedical engineers recently revealed the secret to their transparent sleeps.

"WHAT WERE THE FROGS DOING WITH THEIR BLOOD?"

The question consumed Carlos Taboada for years. As a postdoctoral fellow at Duke University in biology and biomedical engineering, Taboada spent his days studying glassfrogs—tiny, lime-green frogs that populate portions of Central and South America and like to spend their days sleeping. A self-professed "frog guy," he'd spent more than a decade studying different species of frogs and the biochemistry behind their coloring and fluorescence.

After earning his PhD, however, Taboada had a new goal: he wanted to understand how the aptly named glassfrogs become practically invisible.

"When glassfrogs are resting, their muscles and skin become transparent, and their bones, eyes and internal organs are all that's visible," said Taboada. "These frogs sleep on the undersides of large leaves, and when they're transparent, they can perfectly match the colors of the vegetation. They barely even leave behind a silhouette."

Taboada had the opportunity to study the clear

amphibians when he joined Sönke Johnsen's lab in 2018. Johnsen, a professor of biology at Duke, specializes in visual ecology and biophysics, and his lab investigates topics spanning bioluminescence, vision, light and camouflage in the deep sea. Johnsen had studied transparency before, but the skillset was primarily limited to marine animals.

"For a tissue to be transparent, light must pass through it without being scattered or absorbed," explained Johnsen. "But animal tissue contains components like cells, fibers, nuclei, nerves—you know, the things that are required for life. But these things scatter light. If you're going to be a transparent animal, you have to find a place to put all that stuff, at least temporarily."

According to Johnsen, most transparent animals, like jellyfish, glass squids and zooplankton, can manage to become see-through because they don't have too much of this internal machinery to camouflage. Their metabolisms are slow, their circulatory systems are simple, and they are weak and fragile, which means they don't have to hide layers of tissues. Their environments in the ocean also help with camouflage, as any non-transparent components can blend in with the surrounding water.

"The problem with studying transparency on land is that there aren't many animals that do it," said Johnsen.

Taboada hadn't been the only scientist to contact Johnsen about the mysteries behind the glassfrogs' transparency. Around the same time Taboada joined the lab, Johnsen was approached by Jesse Delia, who was pursuing postdoctoral research at Stanford University. Delia had studied the behavior of glassfrogs for his PhD, and he'd spent countless nights observing the parental behavior of the amphibians in their native forests.

But during a research trip to Panama, Delia stumbled upon a sleeping frog during the day—an unusual occurrence due to the nocturnal schedule he'd adapted for his field work. He was surprised by





Glassfrogs are strict leaf-dwelling frogs, that sleep, forage, fight, mate and provide (male) parental care on leaves over tropical streams. Photos by Jesse Delia.

"These frogs sleep on the undersides of large leaves, and when they're transparent, they can perfectly match the colors of the vegetation. **They barely even leave behind a silhouette**."-CARLOS TOBOADA

the lack of blood circulating in the animal and captured a video, zooming in on the amphibian's heart. He saw that instead of red blood circulating through the frog's system, clear fluid was being pumped from the organ.

"As soon as I started nudging the frog to wake it up, a swell of red blood cells appeared and started circulating," said Delia. "But when I let the frog rest and go to sleep again, the cells would disappear."

Johnsen immediately connected the two scientists. "It was just one of those things where the right people came together at the right time," said Johnsen. "Carlos and Jesse generally have different personalities and research backgrounds, but they came in with a huge amount of respect for each other's talents and abilities, and they developed a strong scientific friendship over these frogs."

Over the next several months, Taboada and Delia set up colonies of glassfrogs—one at Stanford and one in the sub-basement of the Biological Sciences building at Duke. After several visits and countless Zoom calls, they developed a theory about how the frogs were able to become transparent.









"We could see that the frog was doing something to conceal its red blood cells, because once it removed them from circulation it could achieve transparency," said Taboada.

This made sense. Red blood cells are especially adept at absorbing green light, which is the color of light usually reflected by plants and other vegetation. In return, these oxygen-rich cells reflect red light, making blood, and by extension the circulatory system, highly visible, especially against a bright green leaf. The bigger question was—where were the red blood cells going? Delia and Taboada had several ideas, and they thought the most likely location was the liver, based on its size.

But for a see-through animal, the glassfrogs' biology was shockingly difficult to study.

"If these frogs are awake, stressed or under anesthesia, their circulatory system is full of red blood cells, and they are opaque," explained Taboada. "The only way to study transparency is if these animals are happily asleep,

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"When the frog becomes transparent, the blood vessels fill with plasma, so the circulatory system continues to function, but with one-tenth of the blood cells that it normally uses. There's basically no oxygen delivery to the tissue when the frogs are asleep."-carlos toboada









Left: Photoacoustic microscopy images showing circulating red blood cells within a glassfrog while asleep and under anesthesia (which breaks blood storage). Above: The same glassfrog photographed (left to right) during sleep, under anesthesia and while active. Photos by Junjie Yao.

which is difficult to achieve when you're running tests on them in a research lab."

The frog's temperament wasn't the only challenge. While the team was able to use traditional biological imaging tools like cameras and other optical models to quantitatively measure how the frog's transparency increased during sleep, their technology wasn't able to image where the frogs were storing their blood. This is because the frog's organs are coated in a nitrogen-rich organic crystal structure. According to Taboada, frog researchers suspect that this coating helps protect the organs from damage and UV radiation from the sun. Unfortunately, it also makes them completely opaque.

"We spent a few months trying to brainstorm ways we could show where the red blood cells were going without needing to invasively test the hematocrit values of the different organs," said Delia, who is continuing his post-doctoral research at the American Museum of Natural History in New York City. "We were really banging our heads against the wall for a solution."

That solution came in the form of an engineer. Taboada knew about an imaging technology called photoacoustic microscopy, or PAM, from studying biliverdin, the compound that gives certain species of frogs their signature green color.

The technique involves shooting a laser into tissue. The tissue's molecules absorb the light, heat up and expand, which causes ultrasonic waves to race back to an ultrasound sensor. These signals can be used to make detailed and colorful biomedical images of the tissue and the molecules within it.

PAM seemed like the ideal tool for tracking the red blood cells, because they wouldn't need contrast agents or any injections that would disturb or upset the frogs. Instead, the red blood cells themselves would provide the contrast agent, because different types of cells absorb and reflect different wavelengths of light. The technique is non-invasive, quiet, sensitive, and—in a stroke of luck—available at Duke in the biomedical engineering lab of Junjie Yao.

Since joining Duke in 2016, Yao has explored methods to make PAM faster and more precise, and his lab's state-of-the-art models can non-invasively measure the temperature of deep tissues and track deep-brain activity. Although Yao and his lab have used the technique to conduct full body scans of animal models that show blood flow, organ activity and firing neural networks, they'd never considered using it on frogs, let alone transparent ones.

"When I saw that Junjie was at Duke it seemed too perfect," said Taboada. "I sent him an email explaining why this technique could be very useful for us and to ask if he wanted to collaborate."

"I responded in two minutes," said Yao, then assistant professor of biomedical engineering. "I was so excited and curious about this magic creature, and I later invited Carlos to join our photoacoustic imaging lab as a postdoc to accelerate his frog research."

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Left: A sleeping glassfrog photographed from its back, showing its leaf-green coloration in reflected light. Photo by Jesse Delia.



"Biology is complicated and weird and random because of a multitude of evolutionary or species-specific reasons, where even if you study an animal and you find a reason to explain a behavior or trait, you don't always get the full story. But that wasn't the case here. These results were crystal clear, and that's so rare in biology."–sönke JOHNSEN



Yao adapted his platform so the team could scan the frogs by having them sleep upside down in a petri dish while Yao shined a green laser at the animal. The red blood cells in the frog's body absorbed the green light and emitted ultrasonic waves, which were then picked up by an acoustic sensor to trace their whereabouts with high spatial resolution and high sensitivity.

"First we used high-resolution PAM, which allowed us see what happens to the individual vessels when the frog is asleep," explained Yao. "The second technique was deep penetrating photoacoustic microscopy, and while the resolution isn't as good, it could go deeper into the frog and image the organs."

The results were startling.

When the frogs were asleep, they removed nearly 90 percent of their circulating blood cells, storing what is essentially their entire circulatory system in one organ—the liver.

"When the frog becomes transparent, the blood vessels fill with plasma, so the circulatory system continues to function, but with one-tenth of the blood cells that it normally uses," said Taboada. "There's basically no oxygen delivery to the tissue when the frogs are asleep."

The images and videos captured with the deeppenetrating PAM showed that red blood cells flow out of the liver and circulate when the frogs were active. When the frog goes



"Biology is complicated and weird and random because of a multitude of evolutionary or species-specific reasons, where even if you study an animal and you find a reason to explain a behavior or trait, you don't always get the full story," said Johnsen. "But that wasn't the case here. These results were crystal clear, and that's so rare in biology. It was really exciting."







The team studied several different species of tree frogs as a point of comparison for their study. The ability to store their blood is unique to glassfrogs. All photos by Jesse Delia.





The public agreed. The research appeared on the cover of Science magazine, and was featured in publications including The New York Times, The Atlantic, National Geographic, NPR, PBS and more than 400 other news sites around the globe.

While the initial question had a crystal-clear answer, the team was left with a new set of questions, the most significant of which is how the frogs manage to store 90 percent of their blood in their livers without clotting. This opens up an exciting new research avenue, one that could one day translate to address clotting and other bleeding issues in humans.

Taboada and Delia already have plans to continue to study other aspects of the frog's biology, including how it controls its metabolism and how it prevents damage to its peripheral tissues when its oxygen-rich blood is packed away. Yao, now an associate professor of biomedical engineering, hopes to make the frog imaging work an essential part of the lab, with plans to keep developing and optimizing their large inventory of imaging tools for use on amphibians and other animal species.

"Our successful collaboration has

been a great example of how multiple disciplines can jointly advance science in the most synergistic way," said Yao. "We are extremely excited about the future directions of research we've opened up."

This work, and these collaborations, will continue to extend across departments and across universities. After finishing his postdoc, Taboada accepted a faculty position at Vanderbilt University, where he'll set up his own lab to study the biochemistry, physiology and the evolution of frogs.

"Everything I study will be related to the optics and colors of these frogs, and we'll be able to integrate everything we've discovered and done through this process and learn from it," said Taboada. "We started this work with a really simple research question about wanting to know what the frogs were doing with their blood, and now we've got endless opportunities." 1/0

A Little construction of the second s

Duke Engineering leaned heavily on its alumni and industry contacts to design a new master's program in climate and sustainability engineering.

By KEN KINGERY

TIME AFTER TIME, year after year, one theme kept resurfacing for the civil and environmental engineers on Duke Engineering's Board of Visitors. A global distributor for one of the largest sugar companies in the world saw the same problem that a project leader prepping small communities to brace themselves for climate change did: there were not enough students graduating from college who were ready to implement practical sustainability solutions for a world filled with a ballooning need for the skillset.

But as any motivational sign worth the cardboard it was printed on will tell you, wherever there's a problem, there's also an opportunity.

The group consistently advised Duke Engineering's administration to create a new program to help fill this

increasingly urgent demand, and the school listened. Not only did the administration heed the advice of its alumni, they continued to engage them as they built Duke's new master's program in climate and sustainability engineering.

"We interviewed nearly 100 professionals in this area in the course of developing the plan for our new master's degree," said Henri Gavin, professor and W.H. Gardner, Jr. chair of Duke's Department of Civil and Environmental Engineering. "Every single one of them told us that the demand for this type of a program is strong. One even said that jobs in this space are like the Facebook jobs of the 1990s—growing rapidly and offering a very attractive salary."

"I don't think that level of engagement and
willingness to listen is very common," said John Sartor, president and CEO of Paulus, Sokolowski and Sartor (PS&S), a full-service architecture, engineering, design, environmental and surveying consulting service based in New Jersey. "Actually, engaging and getting opinions from industry to create a better educational experience—that's what made a difference here."

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Beyond Technical Knowhow

With the initial advice from alumni on the Board of Visitors and the go-ahead from Jerome Lynch, Vinik Dean of the Pratt School of Engineering, Gavin was faced with a daunting task. The board members were telling them that there was a demand for engineers ready to lead the implementation of projects in the general climate change and sustainability space.

But what exactly did that mean? And how could he be sure that they were actually right? Having served as a faculty member at Duke for nearly three decades, Gavin was somewhat removed from the industry himself, especially given that he was hearing these jobs are in demand in every sector of the economy.

To do his due diligence and begin building the foundations of a new program, he turned to one of the few social media networks that hasn't been mired in controversy lately—LinkedIn.

"We've maintained a LinkedIn database of all of our students for decades, so it was incredibly convenient



your organization hire each year? How long do you expect this hiring to continue?

The response was a tsunami, and confirmation that he was onto something. The field was quickly shifting. It needed workers equipped with more than technical knowledge—it needed workers who could

to find and reach out to them on that platform," Gavin said. "Especially having been here for 27 years now, there's a ton of value in starting and maintaining these long-term relationships."

Gavin sent a simple, straightforward email to all those who responded to his initial request for feedback featuring a set of thoughtful questions. Where is your company headed in the areas of sustainability, climate change and the circular economy? Are you able to find the technical talent that you need in these growth areas? Are you looking for generalists with broad knowledge or specialists in particular areas? What is provided by existing academic programs, and what is missing? How many of these people would understand the systems they were developing on a much broader basis. How projects will affect not just the client asking for them, but also surrounding communities and other stakeholders. How to talk to professionals about navigating policy details as well as understanding and securing financing. How to communicate effectively with team members with a wide range of skillsets and to the people who will eventually adopt the services being built.

"Uniformly, we were told about the importance of the breadth of understanding of implementation strategies," Gavin said. "How does one convince a municipality that making a closed landfill and pulling out the methane for electricity generation is a good

In 2022, U.S. green job postings on LinkedIn jumped

but green talent grew only U

- THE WALL STREET JOURNAL

idea? It's not just the technical side of things."

Gavin also discovered that the job market was much larger than he anticipated. Everyone he talked to told him that they were having trouble finding workers with the skillsets they needed. Gavin's research predicts a shortfall of climate and sustainability engineers on the order of tens of thousands within only a few years.

With all of this in mind, the decision was made to create a new Master of Engineering degree, rather than an undergraduate degree. The wide variety of expertise provided by students with different engineering degrees and careers would be vital to creating the well-rounded experience needed for such a program to develop the leadership in this area that is so desperately needed. Students at this level would be able to start working on real-world projects for industry partners from day one. And on a secondary level, such a program could more easily draw students from outside of the country, which is important given the low numbers graduating with backgrounds that would prepare them for this type of work within the United States.

"Companies are looking for candidates with practical experience that they can hire into entry or mid-level positions," said Tim Zhang, senior climate manager at the consulting firm Cumming Group. "They want people who can directly take on projects like calculating carbon footprints and findings ways to mitigate their impact."

Evolving an Idea Into Reality

With the structure of a new master's program beginning to take shape, Gavin still needed a crucial ingredient to solidify it into reality—someone to lead it. Luckily, he'd already been consulting with the program's future leader—it's just that neither of them knew it yet.

One of the dozens of industry alumni that Gavin reached out to was Sara Oliver. After graduating from Duke's civil and environmental engineering program in 2006, Oliver went to work for a private consulting engineering firm where she worked on highway design projects.

And then Hurricane Sandy tore through the eastern seaboard, causing an incredible amount of damage to the World Trade Center site. For nearly 10 years, Oliver worked on a flood mitigation program for the landmark, going through everything from preliminary design to full-scale testing and full construction support, and eventually managing the project. From there, she managed a contract for the Federal Emergency Management Agency (FEMA) where INTEGRATIONS

To achieve the United Nation's Sustainable Development Goals, the World Banks estimates the world will need to invest

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in infrastructure by 2030.

she worked with marketing giant Ogilvy to educate communities about flood risk and motivate them to take action to protect themselves.

It's exactly the type of work that the new master's program is looking to prepare students to pursue.

"We were trying to hire people for the FEMA project, and it was hard because nobody trains people in climate change—particularly risk and uncertainty," said Oliver. "That's just not a typical piece of an undergraduate curriculum. And neither are pieces like equity or behavior science, which are foundational to the successful implementation of climate solutions. People won't use something just because you build it or deliver it to them. Communities and end users need

"Industry needs more educational programs with a strong engineering focus on climate adaptation and mitigation projects to draw from."

—TIM ZHANG

to be incorporated in the process from the start. Listening to them must be step one."

Having experienced issues finding the right people to fill roles herself, Oliver was happy to lend her advice to Gavin in the early days of his research. And then in February 2023, after catching up with him, she asked how the search for a director was going, and Oliver decided to apply herself.

"I was very happy at my old job. I loved what I was doing. I still love the team, the mission and the work. It was a really hard decision to make," Oliver said. "But after working through the challenges of finding people and building teams to do this work, I know a program like this is needed and I really wanted to take part in building it."

It's also a need that Oliver feels that Duke is well-positioned to address—a feeling that others who have advised on the project share.

"There are climate and sustainability programs at great schools like Stanford and Columbia, but they seem to be more focused on studying the climate and developing energy technologies," Zhang said. "Industry needs more educational programs with a strong engineering focus on climate adaptation and mitigation projects to draw from."

"For as many university systems as our country has, I've only seen a handful with climate and sustainability programs," echoed Sartor. "And most of them are about researching climate impact rather than implementing climate solutions."

If the growing need for this type of a program wasn't cemented during Gavin's

research and interviewing phase, it has been in the months since Oliver announced she was leading it. Duke alumni with all types of backgrounds have been reaching out to her to partner on developing projects and other pieces of the curriculum.

"These are people who were economics majors that are now doing energy financing," Oliver said. "And they have an interest in engineers that contribute to their field."

And it's not just Duke alumni. At industry conferences over the past several months, professionals from companies that were previously Oliver's competitors have approached her to communicate their approval and offer their help.

"When I left my previous job, people's reactions were, 'I can't be that upset because what you're going to do is so cool and so needed,'" Oliver said. "And that's from my company as well as clients. People want to stay in touch and help, which is a testament to the value of what we are building.

"The other thing that I think is valuable about this program and how it was developed is how much it's brought our community together," Oliver continued. "It's the alums, it's the students, it's the faculty, it's friends of Duke. The alumni association says 'Forever Duke' and that you're always a part of the Duke community, of the alumni network. You still have benefits to be a lifelong learner. I think this is an example of bringing that larger community together to benefit the world, and I think there's a real opportunity to make significant positive change and a big impact, which is remarkable." I/O

BUILDING A PROGRAM'S INTERNATIONAL BRAND IN AN EMERGING FIELD

Thoughtfully filling scholarly gaps in the FinTech industry's global events calendar is building Duke's reputation in the growing field.



By ANNIE GIBSON

EFORE THE GREAT RECESSION upended the American housing market—along with the rest of its economy—in 2008, the top 10 list of mortgage lenders in the country was filled with longtime financial stalwarts. Think names like JPMorgan Chase, Charles Schwab, Wells Fargo or Goldman Sachs. In short, the entire list was filled with banks.

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Fast forward 15 years, and that is no longer the case. While there are still a handful of banks cracking the list, it is now dominated by Rocket Mortgage—which originates more than three times the mortgage capital than any other on the list ranked third or lower—and includes names like United Shore Financial, LoanDepot.com and Fairway Independent.

This shift is emblematic of the quickly expanding field of financial technology (FinTech). Stretching much further than the cryptocurrencies that dominate news headlines, the industry is enabling a revolution in the way money is moved, offering opportunities for new companies to develop faster,

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cheaper, easier and more secure platforms to conduct business.

While the FinTech industry as a whole is quickly spreading its wings and maturing, however, the gatherings where leaders in the field come together to talk shop are not.

"If you go to the largest FinTech conferences in the country, such as Bitcoin Miami in 2023, it's filled

with thousands of people who are there to sell you something," said Jimmie Lenz, director of Duke's Master of Engineering in FinTech program.

"We're holding these events in neutral venues and emphasizing discussion at all sessions rather than hearing people talk. It's proving to be very popular and something people are looking forward to."–JIMMIE LENZ

> Where others might see such a gathering as either a great sales opportunity or a headache waiting to happen, Lenz saw an opportunity. By building a global network of events designed to ditch the disingenuous sales pitches and focus on meaningful conversations between stakeholders, he could help move the industry forward in a meaningful way.

And build the reputation of the program in the process.

Launched in the summer of 2020, students in the program take classes in business and FinTech, are required to take a capstone course, and have an industry internship. Along with the core curriculum, students take three electives of their choosing that are tailored to fit their future goals. At its beginning, the program was supposed to have only 15 students. But demand far exceeded expectations, and the current class has 92 students, over half of whom are women.

To further build the program, and Duke's

reputation in FinTech, Lenz is putting together a worldwide series of discussion—and solutions based FinTech workshops. These events are designed to facilitate effective conversation and provide a space for those in the digital assets industry to collaborate and address growing trends and problems in the industry.

"We're holding these events in neutral venues and emphasizing discussion at all sessions rather than hearing people talk," Lenz said. "It's proving to be very popular and something people are looking forward to now."

Lee Reiners, a lecturing fellow at the Duke Financial Economics Center and at Duke Law, had long noted a lack of conferences of this type in the digital assets and cryptocurrency spaces.

"We recognized that there was a gap when it came to conferences and gatherings related to digital assets or cryptocurrencies, and that gap was really around providing a forum for unbiased serious conversation around all aspects of the digital assets sector," Reiners said. "A lot of crypto conferences are just all about hype, promoting various cryptocurrencies and selling things."

The latest installment of this conference series was held in Washington, D.C. last winter. Before that, "Digital Assets at Duke," was held at the university in January. The next conference will be held in Abu Dhabi this winter with another scheduled for Singapore in the summer of 2024.

Every aspect of these FinTech conferences, regardless of their location, is designed

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to facilitate productive and academic conversation. The conferences are smaller, capped at around 230 to 240 people, and the discussion agenda is tailored to fit the different interests and needs of the region in which the conference is being held. In the United States, for example, conferences focused on builders, centralized exchanges and an emphasis on regulators. In Abu Dhabi, however, most investors are some permutation of sovereign wealth funds, so the programming will cater to their needs and interests.

"Everybody pointed out that that was the number one thing that made the conference so unique, the fact that everybody was able to interact with speakers on every topic that was presented," Lenz said.

The conferences are open to a wide variety of industry players to diversify conversation and resources. Participants include companies involved in digital asset trading and tokenization, centralized exchanges, analytics servicing companies, and lots of investors. Speakers at Digital Assets at Duke in January included U.S. Securities & Exchange Commissioner Hester Peirce and U.S. Commodity and Futures Trading Commission Commissioner Kristin Johnson.

Panels covered an assortment of topics, including technology, policy and regulation, business, and investing. The diversity of subjects discussed is intentional, aiming to bring together key players in the digital assets space in a neutral academic platform in hopes that they will leave with new perspectives they might not have interacted with otherwise.

The need for Lenz's global series of workshops is clear. Even as the field expands and becomes more widely accepted and adopted, there is still much work to be done to integrate its opportunities into the existing political and regulatory landscape.

"There are significant regulatory challenges in multiple countries, and it's not entirely clear how digital assets fit within existing regulatory frameworks," Reiners said. "That can be a real impediment to firms, if they don't know what the rules of the road are, or maybe the rules of the road don't allow

KEY TAKEAWAYS

Identify unmet needs in a field's community.

Plan smaller events where attendees can engage in lively discussions in every session.

Tailor each conference's agenda to the needs of its host city's region.

Target regions around the world with a high concentration of existing expertise.

Invite speakers and attendees from a wide range of stakeholders within the field.

them to operate the business that they want to operate."

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The workshops that Lenz and Reiners are planning aim to address some of these roadblocks to development that financial technology is facing and, ultimately, provide a space for growth, problem-solving and collaboration for the emerging digital assets industry.

"We're definitely trying to build a brand in the digital assets space. When you think of digital assets, Duke is what I want you to think about," Lenz said. "At the end of the day, we want to see the industry grow in a responsible way. We want to see access to good products by more people around the world, and we want to see continued development in the digital assets space." I/O





About the Investors

Joe Saldutti

Managing Director of Gridiron Capital Duke University B.S.E.'88 Harvard Business School M.B.A.'92 Currently serves on the boards of: Carpe, Erie Home, Foundation Wellness, and Leaf Home™. Investments through Duke Capital Partners include: Vertera; InnaVasc; Saas Optics, Carpe, Teamworks, AiFi, Realtime Robotics, and Carbon Robotics.

Samir Shah

Venture Partner of Cervin Ventures and IKJ Capital Bangalore University B.E.'90 University of Alabama M.S.'92 Executive Program, the Graduate School of Business at Stanford University '18 Serves on the board of Revyz Proud to have invested in: AiFi, Tune Therapeutics, Perspectus Al

Ruby Grewal

Executive in Residence, Roivant Sciences Duke University B.S.E.'88 Duke University Fuqua School of Business M.B.A.'93 Serves on the Duke University Pratt School of Engineering Board of Visitors, Caltech Associates Board,

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to date... but excited for more opportunities!

Eric Schiffer

Managing Partner of a family office Former NYSE company CEO Former venture capitalist Duke University B.S.E.'83 Harvard Business School M.B.A.'87 Serves on the boards of UCLA Health Systems and Posse Foundation 100+ startup investments, including Oura Ring, Synthorx, Janux Therapeutics, DTx Pharma, Xilis, AiFi and Tune Therapeutics.

A HANDS-ON ROUNDTABLE Investing in University Spinouts

By FEDOR KOSSAKOVSKI | Illustrations by JOANNE PARK

After a white-hot investing market in 2020 and 2021, the past two years have been tougher for many startups looking to raise new capital. Getting that all-important first infusion of cash is especially crucial for the earliest-stage companies, like startups spinning out of universities.

Luckily, there are still angel investors looking to place bets on potential future unicorns. To better understand what they're looking for and how, we sat down with a few members of **Duke Capital Partners**, the early-stage venture investment arm of Duke University.

This interview was edited for length and clarity.

What are trends in investing and emerging technologies that you are following?

JOE SALDUTTI: We're looking more and more at who are the disruptors. For example, Duke Capital Partners has an awesome portfolio company whose board I serve on—it's growing hand over fist, profitable, but a number of their direct marketing campaigns are through TikTok. So, they are starting to ask the question: What if TikTok gets banned? They now have good contingency plans, but we increasingly need to ask: How does a company weather things that are unforeseen?

SAMIR SHAH: Angel investing used to be a "friends and family" round, but now there's a ton of sub-ten-million-dollar first timer funds that are active in this category. Tech trends that are exciting me right now are: everything foundational AI and ML related, quantum computing–I continue to like that for the longer term–advances on the Alzheimer's front, and space tech, which is always exciting.

RUBY GREWAL: One's angel investment time horizon for returns should be long. My expertise is in healthcare and more specifically biotech. Those investments are driven by the science. What's intriguing to me is learning from experts outside my field of expertise. Some of the areas that Samir talked about—space, machine learning, quantum computing—are all areas where I'd like to dabble and leverage the network's expertise.

ERIC SCHIFFER: One trend relates to valuations which became insane over the past few years, and since most startups fail, for the math to work, an angel had to believe a company could be worth over a billion dollars. Now valuations have materially fallen back to historically reasonable levels. A hot emerging area is personal health and wellness. I'm also seeing a lot of opportunities with transparent pricing being applied to different industries. A classic example of this is the optometrist with randomly expensive pricing for glasses. Then Warby Parker opened with transparent and reasonable pricing—all glasses are \$99—and they took off.

When looking at an investment opportunity, what are you looking for?

SS: People. Fundamentally, everything can change, will change, needs to change—but you can't change the people that you are working with.



ES: The ability of at least one of the founders to raise money is so critical, especially with angel investing. If they can think through the issues and use first principles thinking, you will have confidence that if this team hits a roadblock that they are going to figure out a way around it.

RG: I'm really looking for what the edge is. What's proprietary about that

technology? I want to understand how big the bet is to cross the next hurdle, how long it's going to take, and when are you going to know whether you're going to double down or fold.

JS: Do people really want to buy the business—and the product or service—it if it succeeds? We are all looking at the potential for a valuable exit if it succeeds versus just that it's a really interesting scientific thing that the company or its founders did.

How do you hear about startups coming out of universities?

ES: I'm in Los Angeles and I often hear about opportunities coming out of UCLA or USC, since they host conferences and are active with local angel groups. A university can't just rely on alumni or expect professors to do TikToks—a university has to be a proactive participant in the startup ecosystem. Also, the tech transfer office can play a big function in getting out there, not just to angels but also to corporations.

JS: Here in Connecticut, I would never hear of any technology coming out of Duke, so the opportunity to

invest through Duke Capital Partners set in motion what now has become a pretty prolific pipeline of potential funding opportunities. Frankly, I don't think it can be done in other universities without an organization like Duke Capital Partners.

SS: 100% agree with Joe. Being here in the Valley, there's a whole bunch of accelerators and incubators, so I see a lot coming from those networks. Being part of the Stanford Alumni Association, university-related angel networks like Duke Capital Partners, these kinds of places are a huge deal source for us.

RG: Beyond scientific publications and presentations, I look at large grant awards and campus publications. Universities need to support professors and founders, making sure they're publishing in the right journals, presenting at academic and industry conferences—promoting the work in the right venue at the right time.

What is a university's role in the entrepreneurial ecosystem, especially in the context of spinouts?

RG: One of the things universities should do is support entrepreneurial behavior. There needs to be a balance across teaching, research, and new company formation. You can only squeeze the balloon so much—universities need the infrastructure and the environment on campus to support these initiatives so that professors can engage and invest the necessary time.

ES: Building on what Ruby said, you can't manage what you don't measure. Figure out what is working, what is not working, talk with professors or grad students who are founders and get their recommendations. I would learn from the best out there and then incorporate what makes sense. Perhaps allow angel groups in the area to meet on campus and encourage aspiring faculty founders to attend.

JS: Developing an ecosystem of advisors. If you're a professor of electrical engineering, you might have a great new breakthrough, but you might not know anything about sales, about marketing, about finance. Really good advisors and mentors help bring it from a vision to something that's actually commercializable.

SS: Stanford has a place called Stanford Venture Studio where students toss around ideas, find co-founders, make



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-SAMIR SHAH

going on which tends to lead to good things for everyone.

SS: One of the biggest highlights for me is the sheer volume of high quality, well-researched deals that Duke Capital Partners

provides. Having the right kinds of analysts and experienced investors that make up the team is what sets them apart, something that would behoove other universities to replicate for success.

RG: Campus angel investing is another way to get involved and give back. Duke Capital Partners has allowed me to meet a diverse group of like-minded investors and it's also expanded my awareness of campus programs and activities. As Samir said, the deal volume is much higher than I expected, so it makes angel investing really accessible.

ES: In general, the university could do a better job of communicating the many ways to get involved and be a part of Duke's startup ecosystem. Duke Capital Partners does a fantastic job of letting its members know about investment opportunities. I've been pleasantly surprised with the quality of the deal flow. They also do a good job connecting its members with founders where they can serve as advisors or mentors. I/O

interdisciplinary stuff happen. Universities have a lot of staff that have advisors that an entrepreneur can go to, but it needs to start within themselves. Sounds very zenish, but it's very important for them to understand what they are getting into. This is not for the faint of heart—to start a company that is, you've got to understand the various responsibilities you are taking on.

What are some highlights of working with an organization like Duke Capital Partners?

JS: The experience with the other members of Duke Capital Partners. In the biotech world, I'd be the dumbest investor in the history of investors. But, if Ruby really likes it and she's going to invest, it probably makes sense for me to take a closer look. There's just a lot of learning



Bridges with communities, of FOR them

Students constructing a 122-meter footbridge in Eswantini benefit from the work just as much as those who will use it on a daily basis. | By SARAH ROGERS

he summer is the dry season in Eswatini. When the water is low, it isn't too difficult for the rural communities who live on either side of the Ngwempisi River to cross. But in the rainy season, students on their way to school sometimes wade through water up to their necks, carrying their bookbags and shoes on top of their heads to keep them dry.

In Ngcoseni, the more isolated of the two surrounding communities, nearly everyone had to cross the river regularly, or had a grandchild, niece, nephew, or another relative who did.

It was dangerous. There were injuries. Even deaths.

"The community said, 'We need a bridge here.' That's how this project was initiated," said Emily Hallock, the Duke University student who eventually became that bridge's lead designer.

How did a project in a small, developing country in southern Africa find its way to Duke?

The landscape in Eswatini is just as jaw-dropping as the 122-meter footbridge built by a group of Duke Engineers last summer. But their real memories, they say, are tied to the people they met and worked intimately with to get the job done.

Photos courtesy Engineers in Action/ DEID/Syd Levy/Kyle Abrahm.



On both sides of the river, the communities organized. They submitted a request for a bridge to the Micro Projects Programme, part of the Ministry of Economic Planning and Development in Eswatini. Then Engineers in Action, an international organization that builds critical infrastructure for communities in need, selected the project for a bridge site.

EIA reached out to David Schaad, a Professor of the Practice in Civil and Environmental Engineering at Duke University. He was a longtime collaborator: he and engineering students in the club Duke Engineers for International Development (DEID, pronounced deed) first built a bridge with EIA in Bolivia nearly 15 years ago.

Schaad then submitted a proposal to DukeEngage, a program that sends students all over the world for immersive summers working with communities to solve pressing issues. Schaad has directed programs "Emily worked insanely hard on it," said Anya Dias-Hawkins, also a member of the class and DEID, who served as co-project manager. "There were a lot of late-night calls and 'Oh quick, we gotta get this and push it through."

The previous summer, Hallock and Dias-Hawkins traveled to Bolivia to build a suspended bridge with EIA, so they had some sense of what was involved in such a large project. But when they received the site information for the Eswatini project in November including the length of the proposed bridge at 122 meters—"We were like 'whoa, this is gonna be crazy,'" said Dias-Hawkins.

In addition to design presentations in the class, every stage of the students' planning involved review calls with EIA and professional engineering mentors from its Bridge Corps, from preliminary designs to finalized designs and proposed bills of quantities.



"I'll be able to walk across the first thing I ever designed. This project is so near and dear to my heart, and it motivates me every day I go to work."—EMILY HALLOCK

for DukeEngage in locations all over the world, Bolivia, Uganda, and Indonesia among them.

And that's how a group of 12 Duke students came to Eswatini to help build a 122-meter-long pedestrian footbridge over the Ngwempisi River.

Though built with rudimentary materials, this bridge bears the imprint of a hundred minds and hands. Its fencing is painted in the national colors of Eswatini: red, yellow, and blue.

Before the students even arrived on site, many of them had already put hundreds of hours of work into the project through David Schaad's Spring 2023 course, "Engineering Sustainable Design and the Global Community," and the extracurricular club Duke Engineers for International Development.

"This was the entirety of my spring semester," said Emily Hallock, who belongs to both the class and DEID. "I'd wake up, put a few hours into the project, go to class, then come back to my room at night and work on the project some more." "During the design stages, they'd look at it, give feedback, and we'd rework it and send it back," said Hallock. "It's thoroughly reviewed by professional engineers, but the program allows for significant autonomy for students in the design role."

After they were approved for construction, the students' final report detailed safety protocols, logistics, and other information, like where they would be staying. It was over 50 pages long.

They departed for Eswatini shortly after the spring semester ended. "Get back home, pack your bags, and then you're off to Eswatini," Dias-Hawkins joked.

The cohort of DukeEngage Eswatini students included several who worked on the project through Schaad's engineering course and DEID. "We had such substantial investment in the project before we ever set foot in the airport, which is what really sets this project apart from other DukeEngage programs," said Hallock.

About half of the DukeEngage cohort were students



"It's not enough just to design this stuff. We need to understand the cultural implications, the ethical implications, the policy impacts, the gender and social issues. **We want to be really sensitive to how we enter into these situations."**-DAVID SCHAAD who were new to the project, but passionate about joining.

"We got a lot of people really excited to be part of this," said Dias-Hawkins.

How do you build a bridge from the ground up?

Trick question. You build it from under the ground up.

"It can take a really long time to dig," said Hallock. "This is the longest suspended bridge that [EIA] has done in any of the countries they're operated in. This is also in a floodplain region. So there are massive abutments, massive holes that need to be dug."

When the students arrived in Eswatini, the community members had already excavated a large portion of the foundation.

"Some people in the community spent 20, 30, 40 years working in the mines in South Africa," said Hallock. "Almost everyone is used to doing manual labor. They are extremely competent."

"They were so strong," said Kyle Abrahm, who served as one of the project's construction managers. "And their mental strength as well, it was incredible."

The community's collective commitment to the bridge project was tangible. Some walked over two hours to get to the site every day.

"We had 40 community members on site every day," said Hallock. "There were people on site who I don't think missed a single day of work. A good portion of them were well over the age of 60. Some of those 72-year-olds were the hardest workers."

Community members made all kinds of contributions to the building process. A group of women cooked and provided a huge midday meal to the students and workers onsite. The chairwoman of the community's bridge committee raised funds to pay for gasoline and organized trucks to move materials. A man named Thokozani Nleko, who served as the tool storekeeper, quickly became close to the students. They began every workday by checking in with him at the tool shed.

At many times, the work was slow and difficult, but the students' level of investment in the project, said Hallock, "makes it easy to stay motivated. You're able to have a big picture



DukeEngage Eswatini students in front of the completed bridge on the day of the celebration. From left to right: Harsh Mathur, Emily Hallock, Maya Reeves, Nikhil Arayath, Kyle Abrahm, Palo Silva, Nimaye Garodia, Jackie Ong, Keely Blahauvietz, Diego Ayala, Harrison Kendall, and Anya Dias-Hawkins. Not pictured is Site Coordinator Syd Levy, who took this photo. The students are wearing gifts from community members, beaded necklaces and garments depicting Mswati III, King of Eswatini.

view of it instead of, "'Ugh, we've been digging the same hole for 10 days.'"

Excavation continued for two weeks after the students' arrival. Then they built the ramp walls, stone by stone, until they stood 15 feet off the ground and six feet underneath it. A group of masons from Eswatini hired by EIA led this work.

"They're essentially the foremen of this project," said Harsh Mather, who joined the project through DukeEngage and served as a quality control monitor.

The masons' expertise was an inspiration to the students. The head mason, Mangisi Sifundza, once

invited them to his home village, where they discovered that he was responsible for building most of it. "He practically built his entire community with his bare hands," said Mathur.

After the walls, they built the bridge's towers. Then the anchor.

"The anchor is one of the biggest days of work," said Hallock. "The whole bridge is held by this concrete anchor. It took 60 bags of cement." In the end, it weighed nearly 17 tons.

Each bag of cement weighed 110 pounds and had to be transported to site. It wasn't so bad when they were

working on the near side of the river, because they were able to use trucks and wheelbarrows, but they also had to cross the river to work on the other side.

"We have three guys on our team who can put it on their shoulder and carry it across," said Hallock. "A lot of the time, we're exhausted before the workday even starts."

There were some unexpected hurdles during construction, like when one of the cables fell off the delivery truck on its way to the site. The cable normally required a forklift to move. It weighed nearly a ton.

"Fifteen of us helped lift it," said Hallock. "We somehow got it back into the truck."

"I learned so quickly that no matter what plan you make for construction, it's going to go wrong," said Abrahm. "You just have to, on the fly, get people together, source a truck, drive out, and figure it out."

Once they had all the cables on site, they hoisted them—another big day of work. "You secure the

cable into the anchor by clamping it," Hallock said, "and then you run it over the top of the tower, walk it across the river, pull it as hard as you can by hand and then clamp it in place."

Walking the cables across the river required everyone on site. "This was the first time in the project all of us were working side by side," Abrahm said. "We carried the cable through the river on our shoulders and then up and over the towers."

They hoisted the cables high into the air with a winch, and then dropped them down to let them settle—"setting sag."

Then they continued to fill the abutments with stone. "We form rock chains," said Hallock. "We pass the rock from person to person to person and then throw it in."

Next was decking the bridge—laying down the planks that people would eventually walk across—then fencing both sides.

Safety was paramount throughout the entire

process, especially "because you're operating with limited machinery," said Hallock. "Most of this has been done with shovels and pickaxes and an auto level."

Professional engineers, the students' mentors from Bridge Corps, visited the site regularly to sign off on critical construction stages.

As the bridge neared completion, the students' anticipation grew.

"I'll be able to walk across the first thing I ever designed," said Hallock, sounding awed. "This project is so near and dear to my heart, and it motivates me every day I go to work."

"We're all like, 'we're super close to the end,'" said Dias-Hawkins.

Finally, after nine weeks, that end came.

"Everything was up and ready by Tuesday and Wednesday," said Mathur, "and we were doing these finishing touches on Thursday. [The head mason] Sifundza and all were laying the last brick, and somewhere in the middle he goes, 'I'll miss you, Ndumane.'" (This was a nickname Sifundza gave him, a shortened version of the title "Interior Mason.") "Then I realized, this is done!"

The bridge stood, swooping over the Nwempisi River, spanning a seemingly impossible distance from anchor to anchor. It even had a name: "Nyawoluhla."

On Friday, the students, masons, and community members held a ceremony to celebrate. There was music, dancing, and lots of speeches, and then they all crossed the bridge together.

It was a bittersweet day. The students had to leave the homestead right after the celebration.

"Going into the inauguration knowing it would be our last day on site made it so hard to balance the mix of emotions," said Dias-Hawkins. "It was an absolutely amazing experience, but such a hard goodbye."

On the last day, Thokozane Nhleko, the tool storekeeper, told her that he was so happy and so sad at the same time. "In that moment, we both just stared at each other teary-eyed," she said.

"We did build a bridge," said Mathur, "but now that I look back, I just remember these connections we made."

"What DukeEngage is intended to do," said Schaad, "and has done so well over the last 20 years, is give students a vision for the world around them in ways that are really impactful and tangible and humbling." Teaching engineering students to work in international development, he says, means helping them develop a sense of perspective while working with communities in different countries.

"It's not enough just to design this stuff," he said. "We need to understand the cultural implications, the ethical implications, the policy impacts, the gender and social issues. We want to be really sensitive to how we enter into these situations."

"It's thoroughly reviewed by professional engineers, but **the program allows for significant autonomy for students in the design role."**—EMILY HALLOCK

He rejects the assumption that these communities "need" the students. "They are harder workers. They can build stuff a lot better than we can. They are going to be owning it long after we're gone. This is not something we're giving to them...we're doing this with them, and in many ways, we are the direct beneficiaries in ways that that we will never quite understand."

Dias-Hawkins has now worked on two bridge projects—one as a cultural relations manager in Bolivia, and one as a co-project manager in Eswatini. She said they have helped her decide on a future career path: she wants to focus on disaster relief. "Getting into communities, seeing an issue, and understanding how to deal with it is what this project has given me," she said.

Hallock emphasized how valuable it was to work on a project where a community's needs aligned with her personal goals.

"I could not be more grateful for this opportunity," she said. "It will have a significant impact on the people here, but the fact that they entrusted the design to me, and I'm able to use this as the pilot of my engineering career...it's something that I'm forever grateful for.

"It was a once-in-a-lifetime experience," Abrahm said. 1/0

ADAPTING TO AINSTRE CLASSROOM

How Duke Engineering faculty are working to effectively—and thoughtfully—use generative AI tools

By MICHAELA MARTINEZ

SING AN AI CHATBOT is deceptively simple: users submit a question or a prompt, like "Explain how metamaterials work," and the platform uses a combination of deep learning techniques and language models to scrape the internet for relevant information and compose it into a (relatively) coherent answer.

Generative AI models aren't a new technology, but when ChatGPT was launched in November 2022, news headlines ran the spectrum from apocalyptic to optimistic. The Atlantic warned that "ChatGPT Will End High–School English," while The New York Times created a specialized beat to cover the topic, with articles ranging from "A.I. Poses 'Risk of Extinction,' Industry Leaders Warn," to advice on how office workers can use chatbots more effectively.

But those working in academic institutions have additional concerns to contend with, namely: *How is this tool going to affect our students?*

The concern was well-placed. Students could use these platforms to draft essays in minutes or use the answers provided by the chatbots to complete assignments and study for tests. Many institutions, from high schools to universities, issued outright bans





on AI chatbots, warning students that using the software would be considered cheating.

But that wasn't the case for the Pratt School of Engineering at Duke University.

"It isn't an honor code violation if a student is caught using ChatGPT or other AI chatbots on an assignment," said Jerome Lynch, the Vinik Dean of Engineering at Duke. "We know that these are exciting tools that will shape our future. It's important for students to learn how to use them appropriately."

IT'S A TOOL, NOT A CRUTCH

As an instructor in Duke's Financial Technology Master of Engineering program, Craig Hurwitz has followed the discussions and fears about students using AI to cheat or find shortcuts on assignments. But rather than worry about these potential issues, Hurwitz immediately sought to use these tools to save time and improve performance on tasks like writing assignments.

"As everyone was saying that we need to pump the breaks and stop this, I was thinking about how these tools are already being used in the workplace," he said. "Our students are going to need to learn how to use it, and isn't that what a university like Duke is for?"

Hurwitz, an executive-in-residence at Pratt, designed an assignment for the graduate students in his "Emerging Trends for Financial Technology (FinTech)," course. Students were assigned a case study and told to choose a FinTech approach to address a challenge posed by the case. But Hurwitz required the students to use one of the AI chatbots to create the first draft of their executive summaries. "I had the students import their first draft into a word document and turn the track changes on so I could see how the draft generated by ChatGPT or Bing evolved into their final submission," explained Hurwitz.

"Some students used a very broad prompt and got a broad piece of garbage that they edited into a good final product," he said. "But some students kept iterating their prompt so that each response from the chatbot got more specific. They went through 25 to 30 iterations until they were happy with their final result, and from there they only had to do minor edits for their final submission."

According to Hurwitz, the exercise gave students valuable insight about some best practices for using chatbots. For example, many of the students who continued to iterate their prompt discovered that they received a better response when they asked the chatbot for an initial, simple response in bullet points. They could then ask the program to expand on specific points to help keep the response focused and clear.

In a survey about the assignment, many students noted that they were surprised by how much of a time-saver the program was, even if they had to work through multiple iterations of a prompt. Students who speak English as a second language also commented that using AI chatbots helped them write as if English was their native language.

The exercise let the students see first-hand the limitations of the AI platforms. According to Hurwitz, many students noticed that some of the information provided by the chatbot was incorrect. They also commented that many of the citations were wrong, or that an outdated source was used.

"To me, this is the ultimate efficiency tool," said Hurwitz. "The students saw that there were problems that prevent ChatGPT and other platforms from creating the final product you use, but it was rewarding to see how quickly they could adapt and optimize it for their specific needs."

A DIGITAL Teaching Assistant

Jon Reifschneider first piloted his Classwise platform in his "Deep Learning Applications" course in the spring of 2023. He'd been developing the program since 2020, when he was hired as the director of Duke's AI for Product Innovation (AIPI) WE KNOW THAT THESE ARE EXCITING TOOLS THAT WILL SHAPE OUR FUTURE. IT'S IMPORTANT FOR STUDENTS TO LEARN HOW TO USE THEM APPROPRIATELY. ⁵⁹

Master of Engineering program. Reifschneider wanted to design a tool that could help students learn and provide faculty with specific feedback about how well students understood a specific topic.

"A lot of student assessments are artificial," he said. "If instructors have a better way to see what students had mastered and what topics they were struggling with, they are in a much better position to deliver effective, personalized guidance to their students. And if students can see what topics they haven't mastered or don't understand, they can focus their efforts more efficiently."

Like other AI chatbots, Classwise is trained on data. But rather than open it up to scrape the entire internet, Reifschneider specifically fed the machine learning algorithms with information from his own teaching materials and lectures.

"Because we keep the data limited to the class and in line with what the instructor is actually teaching, we minimize the problem of the AI hallucinating, which is when it generates incorrect answers but presents them as facts," explained Reifschneider. "We don't get down to zero errors, but we're pretty close."

As students watch lecture videos or complete exercises, the Classwise chatbot asks questions about topics covered in the lesson. The tool then assesses students' answers and provides and



FOR INCORPORATING AI INTO THE CLASSROOM

The proverbial cat may be out of the bag when it comes to Al. Here are a few ways to help students learn about the tool's capabilities—and limitations:

Challenge students to use generative AI tools like ChatGPT or Bing to create first drafts so they can learn how they need to edit the prompts to get the most effective and accurate information.

Students in **Craig Hurwitz's FinTech class** noted that asking for a simple, limited response in bullet points was the most effective starting point.

Have students track where information was accurate and where the weak points in the response were. Was the information out of date, incorrectly sourced, or just plain wrong? Work with programs like Classwise that keep the topics and data limited to the class. This improves accuracy while still letting students learn how to navigate generative Al tools.

Ask students to examine the behaviors of the tech companies running generative Al systems. Do they respond to calls for change? Do they have ethics teams to navigate Al-related issues?

Make sure students are aware of limitations in the data. The internet is full of misinformation. Make sure students can think critically about how and where these tools get their data. explains any information it thinks is missing. Students can also prompt the chatbot if they need further clarification or examples. Once an assignment is submitted, Reifschneider and other faculty review the student responses and identify any particularly challenging topics that may need additional coverage in class.

Reifschneider has already seen enormous success with the program. Several faculty members across Duke have started using Classwise for their fall 2023 courses to engage students in using active learning with the AI chatbot. He has also worked with Duke Translation

& Commercialization to make Classwise available to instructors from other schools and universities, and over a thousand educators and students ranging from middle school through graduate school are now using the tool.

Reifschneider is hopeful that these AI platforms—when used correctly—can serve as an effective complement to instructors.

"Students don't need to wait for me to read and respond to an email if there is something they don't understand in a lesson," he said. "Tools like this have unlimited patience and time, so students can ask as many questions as they want until they feel comfortable with a topic. The opportunities are endless if teachers and students know how to use them effectively."

IDENTIFYING CRACKS IN THE FOUNDATION

Despite their success so far, Duke Engineering faculty aren't blindly adapting AI platforms into their curriculums. Many are still concerned about the ethical quandaries and problems associated with the algorithms that drive the chatbots and their data sources.

Allegra Jordan, an executive-in-residence at Pratt, teaches "Management of High-Tech Industries," a core class in Duke's Master of Engineering Management program that focuses on the skills students need to cultivate to be successful leaders.

Despite the course's title, Jordan's iteration of the course doesn't immediately focus on technology. Instead, her curriculum includes exercises that help students learn valuable interpersonal skills, like how to manage unexpected challenges without panic, conduct difficult conversations, and identify red flags or concerning behaviors in a company's work culture. online data they were learning from.

"There isn't a way for the public to qualify the data that these companies are scraping from," said Jordan. "There is a lot of misinformation online, and if these tools are using and spreading that misinformation as fact, that's something that needs to be addressed."

Jordan is far from the only faculty member with these concerns. Cynthia Rudin, the Earl D. McLean, Jr. Professor of Computer Science, Electrical and Computer Engineering, Statistical Science, Mathematics and Biostatistics and Bioinformatics,

"TOOLS LIKE THIS HAVE UNLIMITED PATIENCE AND TIME, SO STUDENTS CAN ASK AS MANY QUESTIONS AS THEY WANT UNTIL THEY FEEL COMFORTABLE WITH A TOPIC." – JON REIFSCHNEIDER

"For students to be successful leaders, they need to know what their values are, and that requires significant introspection," said Jordan. "My goal is to teach our students how they can make quality, ethical decisions in industries where technology is constantly developing. Unfortunately, those places can have a lot of conflict, which makes that challenging."

During each semester, the class typically explores the leadership and decision-making at several companies as case studies. But during the 2023 spring semester, Jordan had the class focus on several of the generative AI companies.

"There is a gap between what you are told is happening and what is actually happening," said Jordan. "For example, these companies said they were concerned with the ethics of AI, but then they would fire or reduce the size of their ethics teams."

The class also discussed the technology itself. While the students could identify a plethora of uses for the AI chatbots, they also kept coming back to an Achilles heel with the programs: the is an expert in AI. Rudin specializes in interpretable machine learning algorithms, which is an AI that has been programmed to explain how it reaches its conclusion.

But the algorithms that power generative AI essentially work in a black box; they spit out an answer without showing how they got there.

"In the near future, generative AI will be powerful enough to cite sources for its information, and it will also be more difficult to tell apart from human authors," cautioned Rudin.

Jordan thinks that it's just as important for Duke students to understand how these tools work as it is for them to learn how to use them. This context is key for thinking critically about the tools they use and the decisions they make surrounding the new technology.

"We want our students to be able to recognize what doing this work well looks like, whether it's having a team of ethicists or sharing their data sources," she said. "Our goal is for our students to become leaders who can change industries and change what's possible." **1/0**

When It Comes to Outreach, It's in the Community

Two emerging programs at Duke provide valuable lessons on how to build experiences for a diverse set of local students to help expand the STEM pipeline.

By JAMAL MICHEL

BEFORE MAKING HIS WAY TO DURHAM, North Carolina, from New York City, Aaron Kyle firmly believed that engineering design was a great way to get young people engaged in STEM learning. Since shifting from an urban metropolis to a smaller, rural area, that conviction has only been elevated.

The professor of the practice in biomedical engineering at Duke also knew that it was equally important for underserved and underrepresented groups interested in the field to be exposed to STEM and have ample opportunity to apply their knowledge there.

Community outreach and engagement are at the core of what Kyle aims to accomplish as both an academic and an educator. They play pivotal roles in fostering connections, promoting education and driving positive change within STEM so that anyone can get involved and contribute their own unique perspective. One inspiring example of effective community outreach that holds lessons for

anyone working in this space can be found through Kyle's Outreach Design Education (ODE) program here at Duke University.

"This is the first time [ODE] has been at Duke—I just moved here last summer, and I was doing a version of this at my previous institution in New York. [This summer] it had a real spirit of excitement that went along with it, but I think the successes were more attributable to the fact that I had an excellent set of students," said Kyle. Designed to empower marginalized and economically disadvantaged students, ODE has demonstrated its commitment to enhancing access to STEM resources, fostering inclusivity and building strong partnerships with local communities through thoughtful engagement.

The program recognizes the potential of design education to engage young minds, regardless of their background, and empower them to become drivers of innovation. Local middle school students participate in a hackathon put on by Duke's Outreach Design Education program, one of several that are strong examples of how universities can make strides in attracting a diverse set of young students to the sciences.

TANGENTS



Aaron Kyle, ODE program director, provides an overview of the engineering design process at the opening session of the Summer Design Camp.

"If they can define a problem and develop a solution to that problem, then it really gives them a chance to do something

impactful and puts them in the driver's seat, which I hope will be a motivator for younger kids [in STEM]," said Kyle.

"We work with middle schools, visiting local ones and providing these short instructional lessons primarily in the fall. Then in the spring, the focus shifts to bringing kids to campus for a one-to-two-day "hackathon" where we go through the design process and build up some low fidelity prototypes as a crash course," he explained about the structure.

Getting Hands-on With STEM

This past spring, Kyle conducted the inaugural ODE Hacakthon with Lowe's Grove Middle School. Much of the Hackathon's success comes from sustained engagement with schools to strengthen relationships with the university and surrounding community even after the program ends. An ongoing relationship with a specific school can help maintain interest from students who might have missed out on a session, highlighting an important element of ODE's outreach.

The five-week Summer Design Camp for high school students is free for all participants and borrows some inspiration from Kyle's undergraduate capstone design course, which introduces students to the principles of engineering design and

"If they can define a problem and develop a solution to that problem, then it really gives them a chance to do something impactful and puts them in the driver's seat, which I hope will be a motivator for younger kids [in STEM]."-AARON KYLE

offers hands-on activities that build technical competencies.

From engineering design workshops to labs and fabrication sessions that involve the use of 3D printers, microcontroller programming and laser

cutters, Kyle wants students immersed in all facets of design that encourage innovation. "In parallel with them learning engineering design, we charge them with applying the design process to find a problem on their own and develop a solution to it. So, they get a chance to be kind of mini-designers over a five-week span," said Kyle.

Transitioning from a large city like New York to the Durham region posed both unique challenges and stimulating opportunities for the ODE program. While the scale and demographics differed, the underlying principles remained constant—fostering inclusivity, promoting STEM education and empowering youth.

One notable aspect of Kyle's approach is his deliberate integration of Diversity, Equity, and Inclusion (DEI) considerations into the design process. He recognizes that addressing DEI issues enhances the quality of design solutions while nurturing a sense of belonging and purpose among students.

By infusing these inclusive principles, ODE can address challenges that resonate with communities, cultivating a sense of agency and social responsibility.

"Incorporating underrepresented groups, economically disadvantaged kids and firstgeneration kids are foundational aspects of what I do with these programs. However, I don't have any exclusion criteria—anyone can apply and join us. I want to be a part of working with Durham Public Schools because I want to provide these opportunities for kids who might not normally learn at a place like Duke," said Kyle.

Empowering the Next Generation of Scientists

Another excellent example of these types of programs features graduate students working with rising juniors and seniors in high school that gives them the opportunity to conduct practical engineering research.

Kiarra Richardson, biomedical engineering PhD student and NSF Graduate Research Fellow, serves as the current president of DukeREP, a seven-week paid internship that puts local high school students in labs and workshops in collaboration with biomedical engineering departments.

"We wrap a lot of things into this program. It's college prep. We do workshops with them where





we cover writing, we conduct mock interviews, we hold different workshops to help them pick their colleges. But the bulk of DukeREP is them doing a research project with a graduate student and basically doing their best to learn concepts through experiments. They really try and get a feel for how it is to be in an academic space, and DukeREP is completely PhD student-run," said Richardson.

And those PhD students are equal parts researcher and mentor.

Like Kyle, Richardson's focus in DukeREP is bringing valuable hands-on research experience to underrepresented communities of students to prepare them for their future as engineers and researchers. Seeking out participants for the ODE Summer Design Camp scholars present their final project posters. Abigail Harrison (top) shows off an ultrasonic guidance cane for the visually impaired to a guest. Robert Quarles, Jr.'s team (bottom) developed a device to quantify and alert when postpartum hemorrhage occurs.

TANGENTS

"It's college prep. We do workshops with them where we cover writing, we conduct mock interviews, we hold different workshops to help them pick their colleges. But the bulk of DukeREP is them doing a research project with a graduate student and basically doing their best to learn concepts through experiments."—KIARRA RICHARDSON

internship involves its own communication efforts, with Richardson and other DukeREP instructors engaging in conversations both online and in-person at schools and events to get the word out.

As DukeREP's current president reflects on her first year in leadership, she offered insightful advice for those embarking on similar outreach endeavors. Leveraging the knowledge and expertise of those who have previously run comparable programs is crucial.

Opening the floor to collaborative planning meetings, coupled with a deep understanding of team members' strengths, could create smoother operations and proactively problem-solve any challenges.

Richardson also took time to highlight the importance of continuous evaluation and adaptation, emphasizing the need to plan ahead and remain



Lessons for Aspiring Community Outreach Leaders

For individuals seeking to establish their own community outreach programs, Kyle's work on ODE and Richardson's REP program offer valuable insights:

Embrace a Spirit of Partnership

Approach community outreach as a collaboration rather than a one-sided effort. Engage with stakeholders and educators as equal partners, valuing their expertise and insights.

Cultivate Humility and Openness

Acknowledge your limitations and be open to learning from others. Humility creates an environment of mutual respect and enables effective collaboration.

Leverage Existing Resources

Build on the work of others and leverage available resources. Engage with like-minded individuals and institutions to collectively drive change and amplify impact.

Address Deficiencies

Integrate inclusive considerations into your program's framework. By doing so, you empower students to contribute meaningfully to their communities while addressing critical societal issues.

Take Action

While planning and preparation are important, taking the first step is essential. Don't hesitate to initiate your outreach program, even if challenges lie ahead.

ODE Summer Design Camp scholar Emery Anderson celebrates with his parents at the final presentation event. flexible to ensure outreach initiatives thrive.

Both ODE and DukeREP serve as successful templates for how academic institutions can make a meaningful impact on their communities. By understanding diversity, equity and inclusion needs while nurturing the next generation of scientific minds, these programs exemplify the power of outreach to drive positive change.

Through collaborative efforts, thoughtful planning and a dedication to expanding opportunities, ODE and DukeREP hold the potential to transform lives and shape the future of STEM disciplines, starting with eager students in sometimes hard to reach places. 1/0



Making a Positive Mark on CAPITOL

Maintaining a physical presence in Washington, D.C. for over a decade, **Duke in DC** offers insights into the importance of faculty spending time engaging with policy makers.

> By JAMAL MICHEL Illustration by JOANNE PARK

HE RAPID PACE of technological advancement and complex policy landscapes has transformed public discourse over the years. With an increasingly polarized country that often raises questions about the value of a higher education—and the value of federally funded research—it's more important than ever for colleges and universities to be connected to Capitol Hill to shape these conversations and subsequent policy decisions.

Enhanced by a physical presence in the nation's capital, Duke in DC, as part of the Office of Government Relations, has been working on taking a proactive approach to engaging with lawmakers in Washington D.C. to ensure that researchers and educators are seen and heard as not just members of academia, but as North Carolina citizens.

Founded in April 2012, Duke's previously decentralized activities gained a home base and a permanent presence in the heart of Washington. Duke in DC hosts academic programs, DC-based university faculty and staff, alumni receptions, and meetings, as well as other activities and events related to official university business in Washington.

One of Duke's key initiatives in engaging with policymakers is its participation in the annual Public Policy Forum hosted by the American Society of Engineering Education (ASEE). The forum brings together engineering deans from universities across the nation, including Duke and its peers representing North Carolina, to discuss timely topics that concern engineering education and research. Other NC-based institutions in attendance typically to include North Carolina Agricultural and Technical State University, University of North Carolina at Charlotte, North Carolina State University, Campbell University, and several more.

"We generally try to prioritize meetings with the representatives of districts in which [North Carolina's] different engineering schools are located," said Jerome Lynch, Vinik Dean of the Pratt School of Engineering. "Earlier this year, I met with representatives from the Durham area, but also Raleigh and other parts of the state. It was exciting to share with these representatives how congressional legislation directly and indirectly impacts the schools and communities they represent."

The event serves as a platform for academic leaders to discuss pressing policy matters and engage with legislators to ensure that policy decisions align with the needs of academic institutions and their surrounding communities.

The university's engagement with legislators involves dialogue aimed at specific goals and objectives that actively consider the diverse aspects of policymaking. The conversations are framed around key points to ensure that the university's concerns and contributions are effectively communicated.

When Legislation and Research Investment Collide

Duke's conversations with lawmakers often center around the advancement of technology and its impact on society. One recent critical

and ongoing example involves discussions around the CHIPS and Science Act, a legislative effort to invest in the semiconductor industry and related technologies.

Signed into law in August 2022, the CHIPS and Science Act was formed to bolster U.S. competitiveness and innovation in the field of semiconductors and other key emerging technologies, like quantum and artificial intelligence, but also climate, the bioeconomy and more.

"While we might meet our delegates with a mindset of representing our schools and professions, we also meet them as citizens. At a personal level, I want to be engaged in the democratic process and be aware of what's going on as a citizen. That in turn allows me to then be a better leader attuned to how our profession can lean in to ensure our democratic institutions can better meet the needs of our communities."

—JEROME LYNCH

To that end, Duke advocates for comprehensive support, which involves advocacy in the research and development of chip technology in the U.S. to funding educational programs that train the next generation of chip designers.

The university has several training programs funded by the federal government aimed toward filling emerging educational needs, and the CHIPS act could provide another opportunity to grow into this essential role.

"CHIPS is looking at many areas including onshoring semiconductor manufacturing—even if we build new chip fabs, there remains the big question of who is going to work in these plants? Also, what cutting-edge chip technologies are available for computing to keep pace with Moore's Law?" asked Lynch. "From educational programs to train future chip designers to highly skilled technicians to work in these plants, universities must show legislators how they can help build tomorrow's critical workforce in a comprehensive manner."

Another dimension of CHIPS that Duke is advocating for is quantum computing. With the potential ability to simulate quantum effects and solve problems too complex for traditional computers, the technology has the potential to revolutionize many critical fields ranging from materials science to cybersecurity. Duke has made significant investments in this space over the past several years, which highlight the transformative nature of legislative support and how far reaching the conversations in D.C. actually are when an institution's ability to innovate and compete are amplified.

According to the Duke Quantum Center (DQC),

its members have helped bring in over \$170 million in funding and performed over \$100 million in government contracts since 2007. Over the last decade, the center has contributed to some of the most impactful collaborations and research studies in the field of quantum computing. For instance, in 2015 the DQC designed and built the first fully connected and reconfigurable universal quantum computer, and another in 2017 before releasing it in 2019. According to the DQC, it was the most powerful quantum computer on Earth "with up to 32 fully connected qubits and better than 99

percent fidelity on gates." The amplification power can also be seen through the lens of the launch of IonQ, the first pure-play quantum computing company to be listed on the New York Stock Exchange that was valued at \$3 billion as of September 2023.

Collaboration is crucial to Duke's success in engaging with policymakers as well. Their representatives work closely with experts who possess in-depth knowledge of legislative processes and ongoing discussions. This collaboration aids in crafting effective talking points and aligning priorities with legislative opportunities.

"We work to bring up experts, not just from Duke Engineering, but from an interdisciplinary group of schools, often to talk about an issue from multiple perspectives," said Jeff Harris, Duke in DC's director. "That allows us to come to singular topics from different disciplines, which makes Duke's expertise more valuable for policymakers and their staff."

Duke's approach to engaging with lawmakers is not solely about academia; it's also about civic duty. As citizens, the university believes
academic leaders have the responsibility to contribute to informed policy decisions. Their involvement goes beyond advocating for their institutions—it extends to supporting policies that foster societal progress.

Both Lynch and Harris highlight the importance of the flexibility of researchers and academics to be able to engage in a number of different talking points when participating in these influential spaces.

"We're lucky we have one of the best government affairs teams here at Duke. They really keep their finger on the pulse with Congress," said Lynch. "They know what all the legislative actions are no matter their state of play—what's in play and what's going to be in play. They are also helpful toward telling us what might not get through even if headlines suggest otherwise. This insight is invaluable as we think strategically about how Duke can meaningfully contribute to national priorities in all relevant venues."

The practice of communicating with lawmakers is not limited to a select group of faculty members or administrators. It's an inclusive effort that seeks to involve a diverse range of voices, perspectives and institutions. By doing so, stakeholders can offer a comprehensive understanding of complex issues and are able to contribute to evidence-based policy decisions.

Speaking the Same Language as Policymakers

Another example of Duke's engagement strategy is faculty involvement in briefings hosted by federal agencies, like the National Science Foundation (NSF), and other groups like professional and scientific societies. These briefings provide an additional platform for Duke experts to share their insights with policymakers and stakeholders on topics like climate finance and research. Melissa Vetterkind, assistant vice president in Duke's Office of Government Relations, pointed to the importance of these engagements, emphasizing how they allow Duke's experts to connect with policymakers and offer valuable researchbacked insights on critical issues.

"Although we develop a number of Duke-sponsored engagement opportunities for the Duke community, it's wonderful when Duke faculty are handpicked by outside groups to share their expertise with a congressional or federal audience. We play a supporting role in these situations to help amplify the event and messages with Duke's key constituency in Washington," said Vetterkind.

Earlier this year, April Brown, professor of electrical and computer engineering at Duke, attended an NSF briefing that focused on showing Congress the strides that NSF has made in advanced

Duke's Pennsylvania Avenue Address

The original Duke in DC office space had five offices and a classroom, encompassing a size that was about a third of the size of the current space. That new office space opened in February 2017 and has about two dozen offices and another two dozen workstations for full-time staff in the region, alongside multiple meeting/seminar rooms, a conference center, a video studio and swing office space available to Duke faculty and staff.

The new space has allowed for a wide variety of programs to be hosted on site, such as professional seminars, alumni events and academic conferences. The office (along with its spectacular rooftop view, seen here) can host everything from an individual faculty member wanting some space to work while in town to the University Board of Trustees, which it hosted in 2017.

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Key Takeaways

Advocate as a citizen of your school's hometown, not just on behalf of your own individual university, prioritizing meetings with local representatives.

Coordinate with representatives of other schools and universities in your region to strengthen your dialogue.

Amplify your advocation by focusing on policy and legislation that aligns with your school's current and planned research strengths.

Include visits and messages from faculty and staff in a wide variety of disciplines and perspectives.

Prepare short one-page descriptions to reinforce the core aspects of complex research topics.

Maintain strong ties with expert faculty, researchers and alumni working on Capitol Hill to provide a foundation for reaching out and collaborating.

Invest in a large physical space in the heart of D.C. to enhance your presence by offering opportunities to host seminars, alumni events and academic conferences.

manufacturing. Several principal investigators were invited to speak in front of a delegation, with each member representing different areas of research funded by NSF.

Brown's area of expertise lies in semiconductor materials and device synthesis and manufacturing. Recently her focus has shifted to quantum devices underlying quantum information applications. This covers areas such as quantum sensing and quantum information technology. During the briefing, each participant, including Brown, had the opportunity to discuss their work for a brief period. Following this, a breakout session was organized, featuring various exhibits, and as part of Brown's presentation, they prepared short one-page descriptions outlining the core aspects of their research.

"There was a lot of interest from congressional staff people who were very enthusiastic and put forward a lot of good questions during the briefing," said Brown. "This was also during the time of the CHIPS Act, although it hadn't been funded yet, and it was important that we shared our thoughts on why it was necessary to fund it."

NSF briefings allow researchers and academics to showcase crucial findings that need to get to the policymakers in charge of bills like the CHIPS Act, and Brown and her team highlight the importance of being in the same room.

Maintaining a Strong Foundation

When not taking part in events planned by federal officials, the process of keeping Duke's experts connected to policymakers involves leveraging a network of relationships and contacts. Strong ties to expert faculty, researchers and alumni working on Capitol Hill provide a foundation for reaching out and collaborating on various initiatives no matter where they're located.

"D.C. is busy, and people have plenty of invitations to professional events and networking," said Harris. "It takes staying in touch and thoughtfully designed programs to make it worth someone's time."

From social promotion to direct emails, preparing for an event and encouraging attendees to participate hinges on the relationship building that Duke in DC and the Office of Government Relations staff help maintain. Keeping stock of these strong ties also allows participants to take on leadership roles with important figures in the industry.

"While we might meet our delegates with a mindset of representing our schools and professions, we also meet them as citizens." said Lynch. "At a personal level, I want to be engaged in the democratic process and be aware of what's going on as a citizen. That in turn allows me to then be a better leader attuned to how our profession can lean in to ensure our democratic institutions can better meet the needs of our communities." I/O

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WE HOPE YOU'VE ENJOYED the inaugural edition of I/O magazine from the Duke University Pratt School of Engineering, and that you've come away with new ideas and thoughts to help further your own endeavors. We'd love to hear your thoughts.





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