Spectrum

HOW WE LEARN

PLUS

MIT LAUNCHES THE CAMPAIGN FOR A BETTER WORLD

Wide Angle

Subjects

FRONT COVER

BACK COVER

Education for a Better World

Breakthroughs

Inside the MIT Campaign for a Better World

The MIT Campaign for a Better World

At MIT, we focus on inventing the future. We push past the edges of human understanding. We make new ways of seeing, and we see new ways of making. We inspire our extraordinary students, and they inspire us right back. We take on great challenges. And through clear-eyed, hands-on problem solving, we deliver new knowledge, new tools, new seekers, and new solutions—and we open wild new frontiers.

In that sense, MIT's greatest invention may be itself—an unusual concentration of unusual talent, restlessly reinventing itself on a mission to make a better world.

Since MIT was founded to help a young nation seize its future as an industrial powerhouse, the people of MIT have been busy solving hard problems and answering big questions, and they have left society transformed. Today, everyone at MIT is hacking societal problems. And we see humanity's pressing global challenges as invitations to action.

As we look to the horizon, we see a future where fundamental science unlocks vital new knowledge and unleashes unprecedented innovation…where climate change yields to climate action…where clean energy is as universal as the sunrise…where every member of the human family can count on clean water and nourishing food…where smart cities inspire wise communities, and the digitally daring drive bold advances for humanity…where we converge on ways to detect disease before it has symptoms, to reduce cancer to an inconvenience, and to make a vaccine for HIV as routine and effective as a tetanus shot…where Alzheimer's itself is just a memory…where new nano-everything solves old, enormous problems…where good ideas don't languish in the lab but flourish in the marketplace…where daring companies of every size create thriving industries and achieve lasting progress…where prosperity is measured not in dollars alone but in the currency of art, culture, and understanding…where quality education is radically more available and massively more effective…and where we offer the world's undiscovered talent a digital path to a creative future.

As we strive to meet these challenges, we seek allies who share our sense of mission, urgency, and infinite possibility. We invite you to join us in creating the future.

This is the MIT Campaign for a Better World.

Let's get started!

L. RAFAEL REIF

MIT (🌐)

(↗)
LEARN MORE
betterworld.mit.edu

Hilary Zelson

VISITING STUDENT
MIT Program in Art,
Culture and Technology

WORKING ON
rooster sculpture
for local preschool

RECENTLY LEARNED
CNC router

**Akwasi
Owusu-Akyaw '17**

UNDERGRADUATE
Course 2
(mechanical engineering)

WORKING ON
motorized skateboard

WANTS TO LEARN
TIG welding

Julian Delerme '18

UNDERGRADUATE
Course 6 (computer science)

WORKING ON
coffee table and shelves
for dorm room

WANTS TO LEARN
3-D printing

Amy (Xiaoyu) Zhao SM '15

GRADUATE STUDENT
Course 6 (computer science)

WORKING ON
personal art project

WANTS TO LEARN
laser cutter,
CNC lathe

Made Here

Inside the Hobby Shop

—

MIT's campus contains more than 130,000 square feet of maker spaces, from student-run shops that promote creative tinkering to high-tech prototyping spaces, and everything in between. And as the Institute reimagines its campus for 21st-century education, innovation, and research (see page 32), the range of available maker spaces will increase and weave more tightly than ever into life at MIT.

Mobius, a new app released in March, will help members of the MIT community navigate this profusion of resources and quickly gain the access and training they need. Project Manus, led by MIT Maker Czar Martin Culpepper SM '97, PhD '00, developed Mobius in partnership with students, shop managers, alumni, and MIT's Information Systems and Technology office. The first of its kind, the app was realized through the support of the Lord Foundation of Massachusetts and MIT alumni Colin Angle '89, SM '91 and Erika Angle '04. The goal: make it easier for MIT students to make what is on their minds—whether they're unwinding with a hobby, completing a class project, or pursuing entrepreneurial inspiration.

This semester, *Spectrum* visited the Hobby Shop, one of MIT's longtime maker spaces open to the entire community, for a glimpse of what students there are building and what tools they've learned to use, or would like to.

PHOTO: LEN RUBENSTEIN

(↗)

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Rewards and Struggles

A design and planning course wrestles with questions of identity, voice, and democracy

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TITLE

11.312 Engaging Community: Models and Methods for Designers and Planners

INSTRUCTOR

Ceasar McDowell, Professor of the Practice of Community Development, Department of Urban Studies and Planning

PHOTO: LEISE JONES PHOTOGRAPHY

McDowell: "Everything Katarzyna does is prototyping to get people into the mindset of experimentation. Rather than the planner driving change, it lets the driver be the fact that people are finding a space to use their imagination and interact with others."

McDowell: "Students who come to MIT have an incredible opportunity and privilege to shape the world; and yet, the world does not do a good job of enabling the broader public to engage with folks who are determining what the city should look like. The kind of people MIT is putting out into the world have to help take on that burden, and ask: how do we open up more space for the demographically complex public to be active participants in shaping the places in which they live, work, and play?"

Subjects

FROM THE CATALOG

As professionals, designers and planners often find themselves struggling to find the "right" way to engage with residents of a community. In practice, designers and planners may use multiple models and methods, even in a single project. This course will review a range of models for engaging communities, from a client-consultant relationship to advocacy, community organizing, consensus building, capacity building, and knowledge building and the ways these different models have been used in design and planning practice and community building. We will examine these engagement techniques within the broader frame of planning as a tool for strengthening democracy.

ORIGINS

Founded in 2009 with professor of landscape architecture and planning Anne Whiston Spirn.

FORMAT

A small, intimate seminar of 9 students meets around a table in 9-450B each Wednesday from 2–5 pm. During the first half of the class, students interview a guest speaker about his or her tools and techniques. The second half of class is open for discussion.

SAMPLE GUEST SPEAKER

Katarzyna Balug, cofounder, Department of Play, which builds "momentary and irresistible fictional worlds" in public spaces for communal exploration of civic issues and policies.

FROM THE READING LIST

- **Kenneth Bailey**, **Lori Lobenstine**, and **Kiara Nagel**, "Spatial Justice: A Frame for Reclaiming Our Rights to Be, Thrive, Express, and Connect"

- **Michel Foucault**, *Fearless Speech*, Chapter 1, "The Word Parrhesia," and Chapter 4, "Public Life"

- **Michael Jacoby Brown**, *Building Powerful Community Organizations: A Personal Guide to Creating Groups that Can Solve Problems and Change the World*

PRACTICAL ELEMENTS

Working in groups, students will design and present an engagement plan for a citywide project. Each team will develop guidelines for engaging with the community in one of the following areas: framing, creating possibilities, setting limitations, or coming to agreement.

GOAL

To make students more comfortable working with communities, particularly communities very different from their own, and help them develop a deeper understanding of their community planning needs.

—Michael Blanding

McDowell: "As planners, we have a real focus on making a difference in the world, in particular for communities that are really struggling. For a lot of students, questions of identity and voice come up with them when they think about entering places they are not necessarily from, and we wanted to make sure they had a space for thinking about their own practice."

McDowell: "We are trying more than anything to get at the rewards and struggles the guest speaker has experienced in working with communities and engaging communities in planning processes."

McDowell: "How the city is constructed has embedded in it messages about social justice—understanding how we use that space can have real implications for fairness and equality."

McDowell: "In order to make these guidelines more robust, each student will find someone they consider 'other' than themselves, and through extensive interviews will build a written portrait describing that person. These portraits will then be used to 'interrogate' the plan, asking how it will work for these particular people."

The Incredible, Edible Pneumatic Interface

A reception on campus one evening this past January featured an unusual cooking demo. Or at least, it would be unusual if this weren't MIT, where technologically enhancing a glob of mozzarella or puffing up bright, sugary balloons seems an almost natural outcome of the Institute's idiosyncratic Independent Activities Period.

The eight-session class, Inflated Appetite, was billed as "an exploration of food as pneumatic shape-changing interfaces." Crackers, ice cream, and chocolate were also on the menu for experimentation. The instructors included Lining Yao and Jifei Ou, PhD students in the MIT Media Lab's Tangible Media group; Wen Wang, a chemical and biological engineer in the Department of Chemical Engineering; and Chin-Yi Cheng, a computational architect from the Department of Architecture.

The course investigated two main approaches to smart material invention with a culinary twist. The engineering approach introduced students to a food printer and an electronic pneumatic control toolkit, including an Arduino-based programming board students used to manipulate inflation of the edible objects. With the biological approach, the instructors focused on how the culturing and fermentation process of yeast applied to the control of bread growth.

Afterward, Yao and Ou blogged about the project: "If we think about the process of cooking, it is all about utilizing the right energy stimuli to create the desired shape-changing, or transformation….To material hackers and designers like us, the kitchen becomes a playground."

Student Sam Chin experiments with melted sugar.

PHOTO: JOHN WERNER

Education for a Better World

MIT (🌍)

At MIT, we pursue research, education, and innovation with a passion for serious impact. We have a record of transforming society for the better—and we're just getting started. We are aiming our gaze straight ahead, at a future filled with important challenges and inspiring opportunities. We are launching the MIT Campaign for a Better World because, with your help, we know we can build one.

MIT's educational mission does not run parallel to these ambitions—it powers them, as these pages show, inextricable from our commitment to research and innovation. Whether in classrooms or labs, residences or maker spaces, in the shadow of a volcano or by the light of a laptop, MIT continues to push the limits of how learning happens, and what it can achieve.

Strength in Education

New initiatives in residential and digital education go *manus* in *manus* with MIT's mind and hand ethos

—

In the cozy "family room" of the McGovern Institute for Brain Research at MIT, neuroscientist Rebecca Saxe PhD '03 is chatting with a group of parents, some holding infants and others reclined on a striped rug alongside their toddlers, who play in the shadow of an enormous teddy bear. Saxe is outlining the puzzle, as she puts it, of "why babies know so much but can do so little."

She summarizes for her visitors—many of whom have enrolled their children in her studies, or will, she hopes—the results of past research indicating infants as young as six months comprehend a surprising amount about their world: connecting words to objects, registering differences between faces. She displays images of adult and infant brains, noting that the "white matter" abundant in the older brain is nearly absent in the baby's. "Maybe white matter is necessary for coordinating action," she hypothesizes, "but learning, which can be done more slowly and offline, doesn't depend on that."

The Saxe Lab's researchers use custom, quiet MRI machines rigged for babies' safety and comfort—and call on reserves of infinite patience, waiting for their tiny subjects' rare moments of stillness—to measure oxygen in various regions of the brain while projecting video of landscapes and faces. The results so far have delighted Saxe: "I could not believe how beautifully organized these tiny baby brains already were!" she marvels, which supports her premise: "Babies are the fastest, most efficient learning machines ever invented."

There are many reasons why scientists study the human brain, but Saxe is one of several members of MIT's Department of Brain and Cognitive Sciences fascinated by how we learn—whether we're stringing together our first sentences or wrestling with advanced calculus. The director of the McGovern's Athinoula A. Martinos Imaging Center, John Gabrieli, studies early predictors of conditions that affect learning, from dyslexia in children to ADHD in adults to Alzheimer's in the aging brain. Gabrieli, who is the Grover M. Hermann Professor in Health Sciences and Technology, has described learning and memory as "the essence of our lives. Everything we learn—our values, our knowledge, our skills—comes from the capacity of the human brain to be plastic and change through experience."

Yet the brain is just part of the picture. Faculty across the Institute are investigating every aspect of the topic, peering through lenses ranging from the social and cultural to the economic and technological, to ask: How do we learn? And how can we learn better?

A new look at learning

Intriguing as they are at face value, these questions are a practical matter for MIT. In his February 2013 charge to the Institute-wide Task Force on the Future of MIT Education, President Reif wrote:

> Higher education is striving to respond to the forces of disruptive change. While many US students struggle to cover the cost of higher education, colleges and universities are straining to cover the cost of providing that education. Yet at the same moment, advances in online teaching technologies are opening up extraordinary new possibilities, suddenly making it possible to offer highly effective but comparatively low-cost advanced instruction to students on campus and to millions of learners around the world.
>
> The positive implications for society are immense and impossible to fully foresee. And I am convinced that these forces offer us the historic opportunity to reinvent the residential campus model and perhaps redefine education altogether. Our society can only benefit if we improve what the residential research university does better than any other institution: Incubate brilliant young talent, and create the new knowledge and innovation that enrich our society and drive economic growth.

Now, MIT has announced several new initiatives (see sidebar, opposite) based on the task force's recommendations. Sanjay Sarma, formerly the Dean of Digital Learning, has assumed the new role of Vice President for Open Learning to unify and steer these widespread efforts. The flagship of these is the **MIT Integrated Learning Initiative (MITili)**, to be directed by Gabrieli.

According to Sarma, who is the Fred Fort Flowers and Daniel Fort Flowers Professor in Mechanical Engineering, "The mission of MITili is to look at learning anew, but also to look at it in a uniquely MIT way, an interdisciplinary way." MITili seeks to transform learning and teaching through rigorous, interdisciplinary study of fundamental mechanisms and learning systems. MITili will consider knowledge acquisition, retention, and mastery, along with motivation, curiosity, and creativity. Among other topics, MITili researchers will examine school effectiveness, the economics of education, and education policy, as well as such social factors as the impact of socioeconomic status on brain development. MITili will share research broadly, within the MIT community and globally to research communities, teachers, administrators, governmental bodies, and other important policy makers.

Laura Schulz (at left) is one of many MIT neuroscientists who study early childhood cognition. In the PlayLab at the Boston Children's Museum, Schulz and her colleagues have observed more than 2,500 children to gain insight into fundamental principles of learning.

PHOTO: M. SCOTT BRAUER

MITx Digital Learning Fellow and Department of Physics lecturer Jolyon Bloomfield (below) conducts a demonstration for students in 8.01 Classical Mechanics. The course runs on a "TEAL+x" model that delivers much of its core content online, maximizing time for in-class interactivity.

PHOTO: BEN BOCKO

MIT's Newly Announced Initiatives in Education

MITili

Drawing from cognitive psychology, neuroscience, public policy, economics, and other disciplines, MITili (pronounced "mightily") is **advancing the science and design of learning** and applying insights from its rigorous research to improving in-person and online education both at MIT and around the world.

MITx Digital Learning Lab

The Digital Learning Lab is composed of 16 MIT lecturers, instructors, and postdocs who serve as digital learning ambassadors in their departments, **building digital content into the MIT curriculum** in collaboration with faculty, developing and teaching MOOCs to a global audience, conducting research on data-driven design, and helping to translate MITili research into practical insights for more effective teaching.

pK-12 Action Group

MIT is home to more than 100 programs dedicated to **improving learning in pre-kindergarten through high school.** Filling a growing need in STEM education, this new group will build on these existing programs and drive new research, technologies, services, and curricula that benefit learners and teachers worldwide.

Digital Learning Solutions

This group of staff collaborates across MIT's departments, labs, and centers, **enhancing continuing education offerings,** and bringing the best digital strategies from across the Institute to serve the growing needs of corporations, executives, and professionals.

Chancellor and Ford Professor of Engineering Cynthia Barnhart SM '85, PhD '88, who shares responsibility with Sarma for several aspects of this work, has predicted that MITili and the other programs announced this past winter will have "far-reaching and tremendous implications for education—for MIT students as well as for students not at MIT."

As the world learns

Two of the new programs provide avenues for applying and disseminating MITili's insights off-campus.

Digital Learning Solutions works with MIT Professional Education and MIT Executive Education to deliver online content with real-world applications to working professionals. The first such course was 6.BDx Tackling the Challenges of Big Data, which featured 12 faculty experts from MIT's Computer Science and Artificial Intelligence Laboratory (CSAIL). More than 10,000 people around the world have already completed it. Subsequent courses have covered cybersecurity, the Internet of Things, and entrepreneurial negotiations, and, most recently, systems engineering in collaboration with Boeing and NASA.

The **pK-12 Action Group** is a new effort that will bring MIT's unique learning approach beyond the campus to learners and teachers around the world at the level of pre-kindergarten through 12th grade. The goal is to fill a growing need in STEM education by initiating new research, design, and outreach activities that will transform how students learn—and increase our understanding of how students learn. Under the leadership of W.M. Keck Professor of Energy Angela Belcher, the interdisciplinary group will build on existing efforts and develop new ones—acting, in her words, as a "catalyst to bring people together, not just people at MIT, but people all over the world" to amplify education "at every level."

Some of the group's efforts, like the Connected Learning Initiative (CLIx), have just taken off. CLIx is a collaboration with the Tata Trusts and the Tata Institute of Social Sciences Center for Education Innovation and Action Research and will leverage educational technologies to integrate active learning and teachers' professional development in STEM areas for underserved schools in India. More than 1,000 schools across four Indian states—Mizoram, Telangana, Rajasthan, and Chhattisgarh—will participate in CLIx, allowing it to reach an estimated 165,000 students by 2018–2019. The program will offer content in both English and regional languages, and will address professional development for roughly 4,400 teachers.

The pK-12 Action Group also provides an umbrella for MIT's numerous and longstanding pK–12 endeavors. Some are research-based, like the Lifelong Kindergarten group founded at the MIT Media Lab two decades ago by Professor Mitchel Resnick SM '88, PhD '92, which has incubated such kid-embraced learning technologies as the programming language Scratch and LEGO Mindstorms robot-building sets.

Others focus on opportunity and access. Since 1975, the Office of Engineering Outreach Programs (OEOP) has provided a taste of MIT's academic rigor and excitement to more than 4,000 middle and high school students free of charge. Up to 70% of the students OEOP serves annually come from underserved communities and up to 80% are from populations underrepresented in science and engineering. Programs such as MITES, MOSTEC, and SEED Academy give a marked boost to their young participants' ambition and achievements. More than 200 of MIT's current students have participated in programs offered by the OEOP. Overall, more than 70% of OEOP alumni go on to pursue majors in STEM fields.

Above right: Through MITES, high school students take courses in math, science, and humanities, along with electives such as architecture or electronics.

PHOTO: GRETCHEN ERTL

Below: Between class meetings, MIT students in the "blended" course 7.06 Cell Biology view specially created MITx videos on difficult-to-visualize concepts, laying the groundwork for group discussions.

PHOTO: BEN BOCKO

Transforming residential education

The digital learning tools of MITx and the global platform of edX have vastly extended MIT's ability to provide quality educational opportunities to all those with the drive and talent to seize them (see sidebar, "Behind the MOOC," page 13). But what about the MIT students right here in Cambridge? By now, in fact, most current MIT undergraduates (85%) have used MITx course content, often through blended learning models that integrate digital content into their regular coursework.

To speed educational innovation on campus, the Teaching and Learning Laboratory (a longstanding office that advises MIT departments) will be joined by another of the new initiatives: the **MITx Digital Learning Lab (DLL).** Rather than a place, the lab is a multidisciplinary community with expertise in learning technologies. Its members will serve as departmental ambassadors, collaborating directly with faculty and other DLL colleagues to develop new MOOCs as well as digital learning strategies and projects geared toward MIT's residential learning experience.

Saif Rayyan is one of the lab's Digital Learning Scientists. Upon his arrival at MIT six years ago, he became interested in the TEAL (Technology-Enabled Active Learning) method implemented at MIT by John Belcher, the Class of 1922 Professor of Physics. TEAL creates a collaborative learning experience through a mix of lectures, simulations, group activities, and desktop experiments. In the spring of 2014, Rayyan joined Belcher in using the tools of MITx to further intensify TEAL interactivity and improve out-of-class learning. In the "TEAL+x" version of 8.02—MIT's physics course on electricity and magnetism taken by more than 800 freshmen at a time—students independently accessed online lessons on core content, along with TEAL simulations and visualizations. The goal: to increase class time dedicated to group projects and discussions. The students submitted many assignments online, so that instead of waiting days or weeks for graded p-sets, they received instant feedback. A summary in the *MIT Faculty Newsletter* noted, "The majority of students raved about the value of automated feedback.... It enabled them to know when they made a mistake and learn from it before submitting the homework. It also reduced their stress about the homework, and raised their self confidence." In a resounding endorsement, 92% of the students responding to a survey recommended applying TEAL+x to other physics courses. Now, both 8.01 and 8.02 are running on the model.

Rayyan and his DLL colleagues are now exploring, among other topics, innovative assessment models. Take Simona Socrate SM '90, PhD '95, a DLL scientist from mechanical engineering, who has run 2.01 Elements of Structures on a blended model since 2013. Socrate recently experimented with a new feature on MITx: if students incorrectly answered a question, followed by a correct attempt, the system asked them to provide a hint that would be helpful to subsequent students who make the same error.

A Digital Boost

Twice a year, the Office of Digital Learning's MITx Grant Program provides a new round of funding for the development and operation of online modules that leverage the edX platform; preference is given to projects that will impact both global (edX) and MIT residential audiences. The most recent call for proposals emphasized teaching methods and new kinds of assessments not possible in the traditional classroom. Selected in March, here's the latest crop of courses set to earn their X:

[3.012X]
Fundamentals of Materials Science and Engineering
Professor Silvija Gradečak (Materials Science and Engineering) and Digital Learning Scientist Jessica Sandland '99, PhD '05

[6.805X]
Foundations of Information Policy
Professor Hal Abelson PhD '73 (CSAIL/Media Lab), Principal Research Scientist Daniel Weitzner (CSAIL), and Professor Michael Fischer (Anthropology)

[7.28.3X]
Molecular Biology
Professors Tania Baker and Steve Bell (Biology) and Digital Learning Scientist Mary Ellen Wiltrout PhD '09

[8.422X]
Atomic and Optical Physics II
Professor Wolfgang Ketterle (Physics) and Digital Learning Scientist Saif Rayyan

[8.04X]
Quantum Mechanics
Professor Barton Zwiebach (Physics) and Digital Learning Scientist Saif Rayyan

[17.571X]
Contemporary African Democracy
Professor Evan Lieberman (Political Science)

[18.03X]
Linear Differential Equations
Professor David Jerison (Mathematics) and Digital Learning Scientist Jennifer French PhD '10

[VPX]
Visualizing the Philippines
Professor Christopher Capozzola (History)

According to Rayyan, the DLL community is paying close attention to qualitative outcomes: efficiency and flexibility for departments; intellectual fulfillment for teachers; and improvements in student attitudes toward subject material, along with overall student well being. Rayyan supplies an example: "There's a lot of research that shows multiple examinations, versus one big exam, reduces stress for students and helps them learn more. We're thinking about whether we can use online tools to transform the experience of exams."

In Rayyan's view, digital tools are a means, not an end. "My colleagues in humanities started doing this a long time ago," he remarks of the "flipped" format. "They expect their students to read outside of class, and use their time together to engage in productive high-level discussion." If well-edited video can prepare physics or biology students for a similarly stimulating exchange with their professor, all the better. "I don't believe in a disconnect between online and in-class learning," Rayyan sums up. "It's really all about learning."

A hands-on twist

As part of its data-gathering, MIT's education task force asked faculty and students to rank the importance of various MIT values and principles.

AUVs, floats, and other seaworthy vehicles (witness this month's dramatic spectacle on the Charles). The sort of place, to point to another recent example, where deans teach freshmen how to construct their own speaker systems from scratch.

The latter experience was offered for the first time last fall. Freshman advising seminars are a half-century-old tradition at MIT. The "Mens et Manus" seminar taught by Freeman and Sarma, along with maker czar Martin Culpepper SM '97, PhD '00 and MechE senior lecturer Dawn Wendell '04, SM '06, PhD '11, gave that format a hands-on twist. The goal was to teach roughly 30 incoming undergrads modern engineering methods that related to their large-group General Institute Requirements. The students received accelerated shop training on such tools as a laser cutter and 3-D printer, and learned to program features for their speakers like flashing lights and Bluetooth capability.

"A lot of the topics we covered, such as resonance and frequency response, lined up with lessons in 18.03 or 8.01," says one of the freshmen from that seminar, Abhinav Venigalla. "It was pretty awesome to take those concepts and apply them in real life."

The adjective his classmate Jane Maunsell applies to the course—"refreshing"—might seem an odd way to describe her conversion of a length of PVC pipe into an oversized sound system. But for Maunsell, that's what it boils down to: "I came to MIT because I wanted to learn how to solve problems. This seminar was a weekly reminder of why I wanted to be an engineer."

"Hands-on experience" received heavy emphasis; faculty ranked it second only to "commitment to excellence," and for students, it topped the list.

The Dean for Undergraduate Education, Dennis Freeman SM '76, PhD '86, recently spear-headed a call for proposals that imaginatively link undergrad education with the overall MIT student experience, including residential life. Many of the proposals, says Freeman, were related to the on-campus maker culture. "I think everyone who comes to MIT aspires to build something," he suggests.

MIT continues to live the "manus" in its motto. At its core, it is the kind of school that commemorates the centennial of its move from Boston to Cambridge by inviting its community to construct

To Freeman, whose ideas for phase two of the seminar include turning it into a residence-based freshman learning cohort, this is exactly the point. "The way you kick off your education is so important. It sets the tone for the whole four years," he avows. "It sets the tone for the rest of your life."

—Nicole Estvanik Taylor

Above left: Students in 2.007 Design and Manufacturing prepare their robots for competition.

PHOTO: DOMINICK REUTER

Below: Undergraduates Tiffany Chen, left, and Minyi Lee collaborate on a software project at the 2015 HackMIT event.

PHOTO: M. SCOTT BRAUER

Behind the MOOC

Since the edX platform was launched in 2012 by MIT and Harvard, MITx has reached more than 1.7 million unique enrollees from 195 countries. Enrollments are one way to measure the impact of massive open online courses, or MOOCs. But each course is different, sparking interactions and outcomes that go beyond the numbers. This is true not only for the many offerings in STEM fields but for MITx courses within the humanities and social sciences, which can take on exciting new dimensions in the digital realm.

[15.662X]
Shaping the Future of Work

Archived courses can be useful to autodidacts, but MOOCs are at their most dynamic when they unfold in real time. A key component of active MOOCs is the online forum, a place for discussion of the material among students, faculty, and teaching assistants. Unfettered by geography, the residential and online learning worlds can augment each other in these forums. For 15.662x Shaping the Future of Work, taught this spring by Tom Kochan, the Geo Maverick Bunker Professor of Management at MIT Sloan, classes from Cornell and Rutgers convened each week in person on their respective campuses with their own professors, working together through the MITx materials for the course. These university students and their professors then joined participants from all over the world in the discussion forums. MBA students from MIT also stepped up as "community TAs" to facilitate discussion around the topics they know best.

[14.73X]
The Challenges of Global Poverty

In selecting its first MITx courses to launch on edX, MIT looked to popular subjects on OpenCourseWare (OCW), a now 15-year-old groundbreaking experiment in making MIT educational materials freely accessible to all. One such course was 14.73, taught by Esther Duflo PhD '99 (Abdul Latif Jameel Professor of Poverty Alleviation and Development Economics) and Abhijit Banerjee (Ford Foundation International Professor of Economics). As 14.73x, it has attracted nearly 70,000 learners. Captain Rajeev Nair of Keerla, India, is one of them. Nair has passed more than two dozen MOOCs, some of which he has accessed while stationed on oil-drilling rigs, and he counts 14.73x among his favorites. Nair runs free math and reading classes for kids in his village. He has said of the MITx course that it "validated my work, as I learned that much of what I was doing in my village were tactics used by NGOs. I will now try out all of the additional successful tactics and models I learned."

[VJX]
Visualizing Japan

Visualizing Japan's digital pedigree goes back to an earlier online project published on OCW, "Visualizing Cultures," a richly contextualized presentation of historical imagery related to modern Japan that was created in 2002 by Shigeru Miyagawa, the Kochi-Majiro Professor of Japanese Language and Culture, and professor of history (now emeritus) John Dower. Some of VJx's video modules feature Miyagawa and Dower in discussion with professors from Harvard (which co-produced the MOOC) and Duke, while other units contain lectures accompanied by curated groups of images. According to Miyagawa, "MITx helped us to develop a suite of assessments that mimic the way historians handle visual material." In one activity, learners use a drag-and-drop interface to compare 19th-century Japanese portraits of Commodore Perry against his photographic likeness. Another exercise asks students to submit the word they think best describes a drawing, before displaying a word cloud of thousands of their classmates' responses. In an unusual reversal, Miyagawa used the VJx materials to create a new on-campus offering of the subject. Now the course has inspired another digital offering, VPx Visualizing the Philippines.

COURTESY OF RAJEEV NAIR

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44%

Digging Deep

MIT Sandbox supports balanced development of student entrepreneurs

In January, MIT announced a new MIT Sandbox Innovation Fund Program that will connect students across the Institute with tailored educational experiences, mentoring, and funding—from $1,000 to $25,000—to test out innovative ideas and hone their entrepreneurial acumen.

Led by the School of Engineering in partnership with the MIT Innovation Initiative, MIT Sandbox is flexibly designed to fit within the context of students' education, research, and other activities. MIT Sandbox will scale up its capacity to serve MIT's entire student body by building on existing resources such as the Venture Mentoring Service, the Martin Trust Center for MIT Entrepreneurship, UPOP, the Gordon Engineering Leadership Program, the Communications Lab, and D-Lab, as well as MIT student groups such as the $100K Entrepreneurship Competition, StartLabs, and many others.

A cohort of seasoned entrepreneurs—representatives of major corporations, as well as individual alumni—have signed on to provide not only financial support but to mentor MIT students hungry for real-world guidance. Students who benefit from the funding by creating successful ventures are encouraged to pledge to give back to MIT or to the MIT Sandbox fund, and to continue to strengthen the program through mentorship as well as giving.

Spectrum spoke with MIT Sandbox's executive director, Jinane Abounadi SM '90, PhD '98.
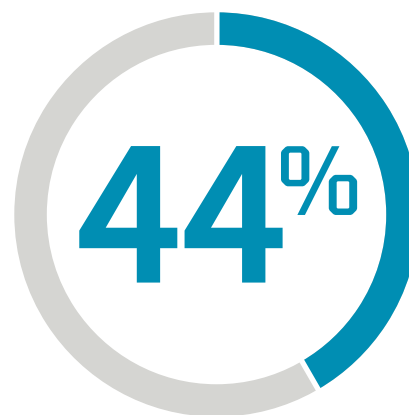
You know the students of MIT very well, having not only been one yourself, but having spent 20 years as a housemaster at MacGregor House. How does MIT Sandbox fit their needs?

JA: I learned from my housemaster days how hard it is for MIT students to navigate all their options without getting overwhelmed. MIT Sandbox looks out for students' overall well being. If they get to the point where it's hard to balance this extra work with their course load and research, we can reassure them that they can come back later, and the money will still be here. That's the thing: in the entrepreneurship world, the message is usually that everything has to be done right away. For students, that can be very stressful and sometimes detrimental. Entrepreneurship success is about the right timing. There is value to taking your time to explore and learn how to solve really hard problems. Some great ideas might come later than sooner in a student journey. MIT Sandbox aims to enable students to figure out the path and pace that's right for them.

If our students are keen to start a company, all of their MIT experiences give them the building blocks: the relationships, the skillsets, the ways of thinking. And part of MIT Sandbox is helping students learn about what type of people they are. The right thing for them may be to start a company, or to continue to be creative and innovative in a research environment, or to innovate within a big company that has significant resources to nurture the entrepreneurial spirit.

It seems that one of the things you and the mentors can offer students is the perspective of hard-won experience.

JA: When I finished my PhD at MIT, I joined BBN Technologies, a great research lab. It was the late '90s and it was right in the midst of the dot-com boom, so in 1999 I left to work on a startup. That was my first introduction to entrepreneurship. It was an exciting time and we managed to land a significant big launch customer. Then the bubble burst in 2000, and

Abounadi, second from right, meets with MIT Sandbox participants.

PHOTO: LILLIE PAQUETTE

the funding dried up and the excitement fizzled away. I came back to MIT as a postdoctoral lecturer because I love working with students. After three years of teaching and research, I wanted to get back to the software industry, and eventually I joined ITA Software and then Kayak. Both were stable, later-stage startups primarily focused on how to best position themselves for a great exit, and they both had spectacular exits. After that, I joined a big company, Travelport, where as the senior director of partnerships and alliances and regional product, I was focused on building a strong network of innovative partners, a good number of which were startups. This gave me quite a bit of experience in seeing which models work and which don't.

I've learned that the road to success is filled with setbacks. MIT Sandbox by definition encourages exploration and risk-taking in an educational setting. Of course we hope—and are confident—that we'll get some great companies out of MIT Sandbox, along with the rich entrepreneurship ecosystem at MIT, but we are not focused on building companies. We're focused on building people and fostering a supportive community of young entrepreneurs.

How will MIT Sandbox guide students in choosing which projects to pursue?

JA: If a student has a million ideas, we can help him or her think through important questions like: Do other people care about this particular problem? Do you really have a solution, or just a dream? Does it add value to society? What work do you need to complete before talking to prospective customers?

The $1K level is meant to lower the barrier for students to try ideas out. Of course, it's not just about the money—you have to put a cocurricular plan together to learn the basics of entrepreneurship, from market validation to fundraising. That can be done either through existing classes or workshops, or with direct advice from a mentor. After the initial round, you may focus on other things and dig deeper for better ideas. If you make progress, you can ask for more

"Our experiences since graduating have given us an appreciation for the value of thinking creatively, exploring ideas with peers, and learning by doing. MIT Sandbox is all of that plus some. We look forward to supporting this initiative and seeing what the students can do with such an opportunity. Our motto is— let students think out of the box and into the Sandbox!"

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Emilie "Mimi" I. Slaughter '87, SM '88 and Frank G. Slaughter '84
are among the founding contributors to MIT Sandbox.

(↗)
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funding, apply to the Global Founders' Skills Accelerator, or enter a competition. By the time you graduate, you'll have built some credibility to launch a company, if that is what you want to do.

I can tell you that a good number of the students we are working with now, a mix of undergraduates and graduate students drawn from the StartMIT workshop, are planning to move forward. These initial projects range from software apps to commercializing sophisticated technologies. This is an opportunity to push them to think very critically about their ideas.

What do you want MIT alumni to know about this program at its outset?

JA: The idea is not to create another competitive program at MIT. It's to create a nurturing way for students to choose the journey that is right for them. We want to reach a diverse group of students who have not already climbed into the MIT entrepreneurship ecosystem, as well as to help position those with advanced ideas for raising funds from external sources once they leave MIT. Getting an equally diverse group of alumni to join the mentorship network will be really important, and we're looking for sponsors that represent many different industries. If it weren't for the alumni support of and dedication to MIT, this program wouldn't be here today. I also want the alumni community to support us in spirit: to believe that this program has the capacity to be a game changer for MIT students in multiple ways.

Informing Education

The School Effectiveness & Inequality Initiative puts facts at the forefront of policy debate

Get good grades, attend a well-regarded school, land a fruitful job—this trajectory is a fundamental tenet of the American dream. Schooling often determines future earning potential and economic mobility. Yet educational choices are often fraught with confusion and uncertainty for students and parents, and for the policy makers who must make difficult decisions about controversial policies and scarce education resources. Are charter schools always a beneficial choice? Do vouchers provide more opportunity? What about expensive scholarships—do they really boost outcomes for students in need?

MIT's School Effectiveness & Inequality Initiative (SEII), based within the Department of Economics, uses rigorous experimental and quasi-experimental methods to examine how education and economics are linked. SEII is helmed by faculty co-directors Joshua Angrist, David Autor, and Parag Pathak and is backed by more than 25 affiliated faculty, postdocs, and graduate students. SEII is the first research group to link the economic theory of market design—that is, the study of centralized school assignment schemes such as are now used in many American school districts—with questions of education policy. Theirs isn't research in a vacuum: SEII's studies have led to major educational reform and policy change since launching in 2011.

For instance, SEII was the first group in the country to produce credible, randomized, lottery-based evaluations of charter schools. Researchers found that some Boston charter schools outperform the city's public schools and that charter schools boost performance of special-needs students and are linked to better MCAS results. These findings were central to the debate over an expanded cap on Massachusetts charter schools. SEII has conducted groundbreaking research on school lotteries, working closely with the former Menino administration in Boston to analyze zone-based and non-zone-based models.

"We don't lobby or seek out politicians; we don't try to influence policy directly. But people who make decisions read our work. We're pro-research, in the rigorous MIT research tradition of putting science first," says Angrist, who is Ford Professor of Economics.

This is important, because clear-eyed educational evaluation has long been overlooked, SEII's founders say. According to Pathak, educational policy debates too often involve "people arguing on ideology instead of facts."

"Other areas—health, energy, et cetera—have pretty well-established traditions of evaluation. In education, we often see people with the best of intentions trying out policies," Pathak observes. "We're trying to build a narrative around compelling case studies, using rigorous experimental methods—methods that allow you to have full confidence in what you're studying, as you would in a medical trial."

Take the question of scholarships in higher education. Much of American education policy is built around an expensive effort to subsidize college attendance for students deemed meritorious, in need of aid, or both. But do scholarships make it more likely that recipients will attend and complete college? Or would these motivated students do well, even without the money? To answer such questions, SEII has worked closely with the Susan Thompson Buffett Foundation (STBF), Nebraska's largest financial aid provider, which gives away thousands of scholarships each year. In their pioneering randomized evaluation of the STBF aid program, the researchers discovered that STBF's awards induced a clear shift from two- to four-year schools, as well as a marked increase in second-year college enrollment on the part of recipients, indicating that scholarships improve retention.

"We knew almost nothing about what actually helps those kids complete college and also whether it pays off for them," says Autor. "The United States is the number-one country in the world at sending kids to college. But we're fifteenth when it comes to those who actually earn the degree. We're good at sending them to college, and not good at getting them through. Studies like the STBF research analyze not only how to get students into college but what keeps them there. This is central to thinking about long-term welfare for the American middle class."

Pathak, meanwhile, has conducted pioneering research on voucher systems. His team evaluated the Louisiana Scholarship Program (LSP), a well-known voucher plan that provides public funds for disadvantaged students at low-performing state public schools to attend the private schools of their choice. These vouchers are allocated via random lottery at schools with more eligible applicants than available seats. His team estimated causal effects of voucher receipt by comparing lottery winners and losers in the first year after the program expanded statewide.

Vouchers might sound promising. But in a newsworthy twist, SEII's comparison revealed that LSP participation markedly reduced academic achievement, lowering math scores by several standard deviations and increasing the likelihood of a failing score by 50%. SEII's team found similar results for science, social studies, and reading, across income groups and geographic areas. Research revealed that the program might attract private schools struggling with enrollment—and thus indicated caution for expanding a voucher system.

"Now we have gold standard evidence of the effect of the voucher program, and you can imagine that the research was controversial," Pathak says.

Education reform gets plenty of media attention, but it's easy to be swayed by the next big trend or splashy idea. "The typical news story is this: A reporter is captivated by something a school is doing, goes there, describes it, says, 'Isn't that neat.' Maybe it's tech, maybe it's child-centered learning, maybe it's built around the arts. For whatever reason, it captures the imagination," Angrist reflects. "But are these good things to be doing to students, does it benefit them in some measurable way that will have consequences? There are many examples where people have a strong instincts about what's good, which somehow blinds them to the facts." By applying quantitative analysis to theoretical ideas, SEII fills the role of fact-checker in a field that crucially needs it. —Kara Baskin

From left, Parag Pathak, David Autor, and Joshua Angrist in the Morris and Sophie Chang Building, home to the MIT Department of Economics.

PHOTO: M. SCOTT BRAUER

Energizer

**An engineer/MBA applies new carbon
capture technology to the fossil fuel industry**

PHOTO: M. SCOTT BRAUER

Aly Eltayeb PhD '15, MBA '17 wants to save the planet—and he doesn't want to wait until he's completed his education to do it. As an undergrad and professional in his home city of Cairo, Egypt, he worked to develop better biofuels. But when he came to MIT as a graduate student in 2010, he saw a different way forward. Rather than fueling a renewable revolution, he focused on the need for a near-term energy transition.

"We have trillions of dollars of assets that use fossil fuels, so we can't just turn them all off," says Eltayeb. "We need to find a solution over the coming decades that will allow us to continue using all that economic value without destroying the environment."

For Eltayeb, that solution is carbon capture and utilization. He found it when he arrived at MIT to begin a PhD in Chemical Engineering Practice, a unique dual degree program that blends a PhD in chemical engineering with an MBA. The program struck a chord for Eltayeb. "I love science, but I don't want to be a

scientist," he says. "My real passion is solving real-world problems."

In the lab of T. Alan Hatton, the Ralph Landau Professor of Chemical Engineering Practice and director of the David H. Koch School of Chemical Engineering Practice, Mike Stern PhD '13, had developed the technology Eltayeb carried forward. Scrubbers that absorb carbon dioxide out of emission gases have been around for decades, but carbon capture technology hasn't been widely deployed. Older technology runs on steam that requires expensive modification to the internal workings of the power plant. Hatton and Stern lowered the barrier to adoption by creating a steam-free plug-and-play system that uses electricity to trigger chemical reactions that capture CO_2.

In fact, Stern and Hatton had answered most of the pressing scientific questions. They had also burned through a good deal of the funding they'd won to support their investigations. When Eltayeb stepped in, the project was perched

on the edge of the so-called Valley of Death. "It's no longer science, but it's not a product," he says. "Who funds that?"

In the energy industry, the Valley is wide and deep. "We're not putting together an app you can just roll out. The energy space is really large scale," says Eltayeb. "MIT is an incredible place to work on these types of problems."

At first, Eltayeb thought that his path would be that of a traditional startup: find venture capital money, build a product, sell it to utility companies. But mentors pointed him toward an alternate route: win grants to develop the technology at MIT, then develop corporate partnerships to advance it.

With the encouragement of the MIT Technology Licensing Office, he applied for two grants, a Massachusetts Clean Energy Center award and an MIT Deshpande Center for Technological Innovation Ignition grant. He won both.

The Ignition award gave him an entree into the Deshpande Center community of mentors, fellow entrepreneurs, and potential customers. With the help of this community, Eltayeb learned that, instead of utility companies, oil companies might have more promise as customers because they have a use for the captured CO_2. They can use it to push oil out of wells to maximize extraction and then keep it sequestered underground. "Think of the implications," he says. "With our technology, you can get oil out of the ground and burn it with a lower carbon footprint."

In the lab, Eltayeb used the new funding to build prototypes and ratchet up performance. His current prototype is significantly more efficient than the previous one, and closer to commercialization.

In 2015, Eltayeb and colleagues in the Hatton lab won a second Deshpande grant. They also won a $1.5 million Transformational Carbon Dioxide Technology grant from the Department of Energy to advance their technology's efficiency. "It's exciting," says Eltayeb, who is due to complete his MBA in 2017. "We're hoping to show that it actually works." —Elizabeth Dougherty

The Head of the Class

**At the Plasma Science and
Fusion Center, research
shapes education—and vice versa**

Last August, an MIT team published a paper with a conceptual design for an "affordable, robust, compact" (ARC) tokamak fusion reactor. Nuclear fusion, the reaction that powers the sun, could offer a near-inexhaustible energy source on Earth. The longstanding challenge has been to design a fusion reactor that produces more energy than it consumes, and that won't require decades and billions to build. The ARC design is remarkable for at least two reasons: it has the potential to surmount those obstacles—and it began as a class project.

The director of MIT's Plasma Science and Fusion Center (PSFC), Dennis Whyte, teaches 22.63 Engineering Principles for Fusion Reactors every two years to a mix of undergrads and grad students from such departments as nuclear science and engineering, physics, mechanical engineering, and electrical engineering and computer science. Rather than assigning problems with known solutions, Whyte puts their intellects and imaginations to work on some of the loftiest real-world goals in nuclear engineering.

Last year's ARC paper, published in *Fusion Engineering and Design*, was no fluke. The previous 22.63 had yielded five peer-reviewed papers. This semester, the class's dozen or so students are hammering out critical details of ARC's interior design. On a Tuesday this past March, the discussion centered on cooling channel geometries and alternatives to tungsten. Whyte sat toward the back of the classroom while Team Magneto and Team Molten Man presented their findings. (The comic-book motif is a running joke; ARC itself references an invention by fictional MIT alum Tony "Iron Man" Stark.) Whyte listened quietly at first, then jumped in with queries or to prompt a new line of thinking. Other visitors—a research scientist, a couple of professional engineers—chimed in with pros and cons for various design options. As everyone packed up at the end of class,
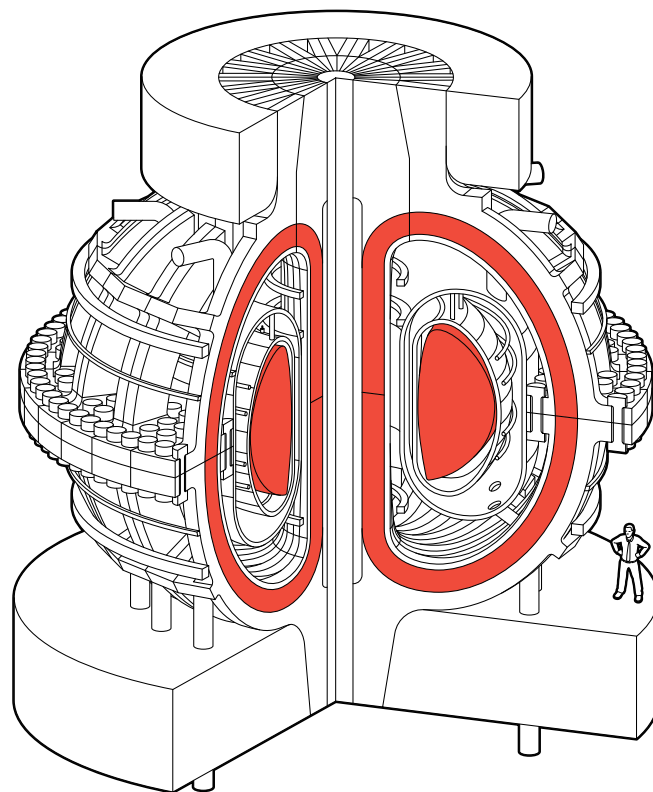
A cutaway view of the MIT team's conceptual ARC design. The doughnut shape is consistent with existing fusion reactor designs; the relatively small size and modular nature of the components are notable. Advances in magnet technology make it theoretically possible for a device of this size to efficiently confine plasma at its center while heating it to temperatures exceeding that of the sun's center.

ILLUSTRATION: CHRIS PHILPOT

Whyte was visibly excited: "I can't tell you how pumped up I am about a neutron-shielded divertor!"

How is it that such promising insights can originate in a classroom, when seasoned professionals are hard at work down the street—and across the ocean—on the same problems? Whyte says his students go down plenty of blind alleys, but have a knack for challenging baked-in assumptions. "Young people don't have what I call the 'everybody knows' syndrome," he says. "'Everybody knows this is how you build a magnetic coil'—they're not saddled with that, yet they're very skilled. That's exactly the way you open up new research venues."

When Andrew Revkin of the *New York Times* commented on the ARC paper, "It's exciting to see academia integrating directly with innovation on this scale," he was zeroing in on a key feature of PSFC: its research and education activities are closely interwoven because they are mutually beneficial.

Whyte can recall at least three moments in last year's ARC class that he considers "major breakthroughs...clever engineering choices that, if they could be implemented, would be groundbreaking to the whole field." He points to the modular nature of the ARC design, which allows its coils to be taken apart and more easily modified and repaired. "That was a student's idea. Everybody knows you can never demount superconducting magnets—except you can, as it turns out."

PSFC researchers are already moving forward with an adapted ARC design. The paper, Whyte says, "was an affirmation of the pathway we are already going down with our research program [the Alcator C-Mod tokamak reactor, operating at MIT since 1991]. It gave the whole lab a better sense of the possibilities." –Nicole Estvanik Taylor

Graduate student Brandon Sorbom, one of the co-authors on the paper outlining the ARC reactor's design, is shown holding rare-earth barium copper oxide superconducting tapes (at left). "Any increase in the magnetic field gives you a huge win," Sorbom recently told MIT News. The new superconductors, which only recently became commercially available, are strong enough to increase fusion power by about a factor of 10 compared to standard superconducting technology such as the large copper conductor at right.

PHOTO: JOSE-LUIS OLIVARES/MIT

Where the Data Flows

Undergraduates get a taste of environmental fieldwork in the shadow of a volcano

Among the most active volcanoes in the world, Mt. Kīlauea is a huge draw for tourists on the island of Hawaii. But MIT junior Rebecca Sugrue wasn't snapping selfies in front of its bubbling lava lake on her recent trip to the Big Island.

Instead Sugrue and six of her classmates were hiking eight miles across the scorched landscape of the Ka'ū Desert, just south of Mt. Kīlauea, to measure the levels of noxious sulfur dioxide emitted by the volcano. "It was surreal," says Sugrue, of her work in this dramatic environment, undertaken through MIT's Traveling Research Environmental Experiences program (TREX).

The undergraduate environment program at MIT first started taking students on weeks-long research trips over Independent Activities Period—MIT's flexible January term better known as IAP—in 2000. "We started offering course credit for TREX a few years back," notes Jesse Kroll, an associate professor of civil and environmental engineering who has directed the TREX experience for the last several years. As of 2014–2015, TREX became a core requirement for Course 1 (Civil and Environmental Engineering, or CEE).

"TREX is how we first introduce students to fieldwork, which is a critical component of environmental science and environmental engineering," says Kroll. "Yet it's often not a part of an undergraduate curriculum because it's challenging to create a full-on field experience, given that it involves travel and a real investment in time and resources."

This year, TREX focused on analyzing the risks of human exposure on the Big Island to volcanic smog (or "vog," as it's known locally), and also included a module led by CEE assistant professor Benjamin Kocar on assessing arsenic content in the soil, an unfortunate legacy of the days when sugar-cane operations used the poison to kill weeds.

Before making the trip to Hawaii, the students spent a week at MIT learning about the environmental challenges of the Big Island, which can go from a desert to a tropical rainforest climate within just a few miles, and building their own air sensors. Designed by graduate students and postdocs in Kroll's lab, the custom air sensors represent an exciting development in air-quality research. About the size of a tissue box and built for roughly $400 apiece, the sensors can operate on solar-powered batteries—a radical departure from a traditional air-quality monitoring site, which requires its own trailer, roughly the size of an office, and access to line power.

"It means you no longer need a $10,000 or $100,000 piece of equipment to make a measurement," explains Kroll. "These little air sensors could be put up all over a city or some area or even on people to measure personal exposure."

Once on the Big Island, the MIT team placed the sensors downwind of the volcano to map the direction, shape, and distribution of the vog plume, with special attention to areas where people live or play. Sulfur dioxide is an irritant that can cause respiratory problems. "Levels are high there, much higher than you'd ever see anywhere on the US mainland," says Kroll. "I

> "Creating a full-on field experience involves travel and a real investment in time and resources," says Kroll.

have asthma and on the bad air-quality days, my lungs were burning."

The fabrication process better equipped the students to understand and manipulate the complex data set generated by sampling the air's sulfur dioxide levels every five seconds. It also helped them better manage the hiccups that occurred once they hit the field, like the fact that the air sensors wouldn't always save the time of day correctly if the battery was running low. The need to work around device failures is common to real field experience, Kroll notes. In this case, the students had to add an extra solar panel to minimize the chances of that error happening and then, once back at MIT, make some software adjustments to determine the correct time of day for the affected results.

The data analysis that took place back on campus over the spring semester may well have publishable results. It turns out the air quality can vary quite dramatically between nearby spots, much as it might block to block

within a city, and depending on the time of day. For the people who live on the Big Island, such data could better inform decisions about safer locations and times for activities.

And for the young scientists themselves, the benefits are perhaps even longer lasting: the experience of working within the environments they seek to understand, and interacting directly with the public whose lives they hope to improve, may influence the way they approach their research for decades to come.

"Local residents would tell us the winds would or wouldn't come in a certain area—and sometimes that changed our plan," recalls Sugrue. "Talking to the community that already exists in that area put some of us outside our comfort zone, which is always a great learning opportunity as well." —Genevieve Rajewski

Sustainability in Action

For S-Lab students, the scale is global, and the stakes are real

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Worldwide demand for water for manufacturing is skyrocketing, placing increasing stress on a limited yet vital resource. Last spring, MIT students took on this real-world problem in a research project for Colgate-Palmolive organized by the Sustainable Business Laboratory (S-Lab), an outgrowth of MIT Sloan School of Management's Sustainability Initiative that is one of several Sloan "action learning labs."

"I learn best by doing, so 'mens et manus' really grabs me, and action learning is part of what drew me here," says Sarah Kalloch, a second-year MBA student who worked on the project during an S-Lab course called 15.913 Strategies for Sustainable Business. "I came to Sloan to study sustainable supply chains in a global context."

Kalloch and four teammates evaluated the advantages and disadvantages of Colgate-Palmolive adopting a "positive water balance program"—a business strategy designed to minimize the impact of manufacturing on local communities by reducing water usage and replenishing supplies. The project was one of more than a dozen sustainability challenges addressed by students for MIT corporate and nonprofit partners during the spring 2015 class. Topics ranged from exploring ways to drive down corporate carbon emissions to evaluating the market for sustainably harvested lobster.

In the case of Colgate-Palmolive, the multinational consumer products company came to S-Lab for help evaluating whether to adopt a "net zero" water strategy for factories in India.

"Water scarcity is becoming a challenge for companies," says Kalloch, noting that she learned through her S-Lab research that Coca-Cola has had to close factories in India due to concerns about groundwater use. "The private sector is looking to emerging markets to find more customers, and for them to be successful they have to look at these issues."

While it is common today to offset carbon emissions in one place with trees planted halfway around the world—essentially producing net zero emissions—it is not acceptable to balance water usage the same way, she says. "Net zero water is a concept built on net zero energy, but the difference between climate change and water is geography," Kalloch says. Water taken from one community cannot simply be provided elsewhere, she explains. "The community isn't made whole in the same way."

To address the company's challenge, the S-Lab team investigated a range of approaches to water scarcity, then developed a decision matrix that enables Colgate-Palmolive to examine available water resources in a region and assess local options for supply and replenishment.

"I think the biggest challenge was aligning corporate interests with sustainability interests and optimizing both," says Macauley Kenney, a master's degree candidate in MIT's Technology and Policy Program who teamed up with Kalloch on the project.

Noting that such optimization is critical to the practical application of sustainability strategies, Kenney praised S-Lab for giving her the chance to bridge the gap between academia and the corporate world. "Sloan's action learning labs are letting students be in both worlds at once, and that's a great goal, because the transition to the corporate world can be difficult," she says.

Another benefit of the class, students say, was the chance to learn from peers as well as academic and corporate mentors. According to Kenney, teamwork is a major strength of S-Lab. "You can get a diverse set of backgrounds working on a short-term sprint project," she says.

Kalloch agrees. "To be a good manager and leader, you need to be very good at working in teams," she says. "That's something Sloan is teaching us through action learning." Noting that she is on the job hunt now, she adds, "This is a perfect example of what I can offer a company—great analysis around challenging supply chain problems." —Kathryn M.O'Neill

Bahr

Springs and Guts

How do you explore medieval poetry with students whose first language is STEM? *Spectrum* **asked literature professor Arthur Bahr—who was recognized as a 2015 MacVicar Faculty Fellow for excellence in undergraduate teaching—to explain his unusual classroom dynamic.**

One of the clichés about teaching is that you learn from your students. It feels especially true to me as a humanist here. I taught at a small liberal arts college for a year before coming to MIT, and I had a great time, but I was talking to people whose interests and modes of thinking were broadly similar to my own. Day to day, I think MIT students challenge me more than students probably anywhere else would.

All literature professors teach close reading: deep, sustained attention to minute particularities of the text that you wouldn't necessarily notice on a quick or even a sustained first read through. Close reading enforces a kind of slowness, and it inculcates the capacity to take your time and to reflect. Particularly at MIT, with technologically driven students, that capacity is one of the incredibly important things the humanities offer.

To get into MIT it's so competitive that you have to be really, really good at math and science, but clearly you also have to have something else. That might be passion for music, or sports. But in some cases it's a passion for reading cool, weird, hard poems—because they're weird and hard. MIT students really like to lean into the difficulty. At many schools, a typical Freshman Comp complaint might be, "I like this poem, but as soon as you make me analyze it, that destroys my experience of it." With MIT students it tends to be exactly the opposite. They might initially say, "There's nothing interesting there; it's just a pretty poem." But as soon as you unpack the syntax of that couplet, as soon as you start worrying over the four different meanings that word has, all of a sudden it opens up a world of difficulty and complexity.

In one class, I ask my students to translate a sonnet into prose, then talk about what is gained and lost by changing the genre. The exercise corresponds to their desire to understand how things are put together, to poke around in the springs and guts of a text. As soon as you show them this under-the-hood side to it, many of them get really excited. And that becomes infectious, because once they get into something, they don't let up.

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IDEAS for New Educational Models

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Since 2001, the MIT Priscilla King Gray Public Service Center's IDEAS Global Challenge has helped more than 100 teams implement projects to improve the quality of life in 44 countries. *Spectrum* **checked in on four of last year's winning student teams, all of which had novel ideas for improving education.**

1 Hands-on STEM in Rwanda
In Rwanda, an estimated 20% of the population achieves a high school education; even fewer continue to college. In partnership with the nonprofit university Kepler, based in Kigali, the Kepler Tech Lab (formerly the MIT–Kepler Education Laboratory) has built a hands-on laboratory to complement the school's on-line STEM courses. The project debuted its first classes in physics, chemistry, and programming in September 2015. Since then the team has renovated and upgraded its lab space, trained four student staff members, and developed and tested 180 hours of engineering curricula.

2 High-quality SAT test prep, for free
At most US universities, standardized tests like the SAT and ACT are required as part of the admissions process. By offering free, high-quality online test preparation, Prepify aims to level the college admissions playing field for students from all economic backgrounds. Prepify also helps connect low-income, high-potential students with college admissions officers and scholarship opportunities. Last August, the team piloted its platform around the country with students from five community organizations: HYPE LA, Breakthrough Austin, American YouthWorks, the Hispanic Scholarship Consortium, and Noble Impact.

**3 Inspiring Latin America's next generation of scientists**
A lag in STEM education is negatively affecting Latin America's economic growth. The Latin American Science Education Network (LASEN) pairs US graduate students and postdocs with students in that region, and—through a combination of project-oriented workshops and digital learning—is helping to educate a new generation of scientists and engineers. To date, LASEN has reached more than 1,700 students and has established clubs in six Latin American locations. The group held events in six cities across Mexico last summer, drawing the participation of 634 students, 82 instructors, 42 science clubs, and more than 300 schools.

4 Bringing learning close to home for Kenyan kids
In rural Kenya, most families cannot afford to pay for boarding costs, leaving students to travel long distances on foot to the nearest school—or forgo school altogether. The team behind 1Room Education (formerly RARE Education) is laying the groundwork for a new model by combining the concept of the one-room schoolhouse with digital learning. The project aims to establish centers where Kenyan students will be able to learn at their own pace, accessing online resources on low-cost tablet computers and meeting with staff mentors.

Collaborative "systems biology" approach
could steer tumors into submission

CORNERING
CANCER
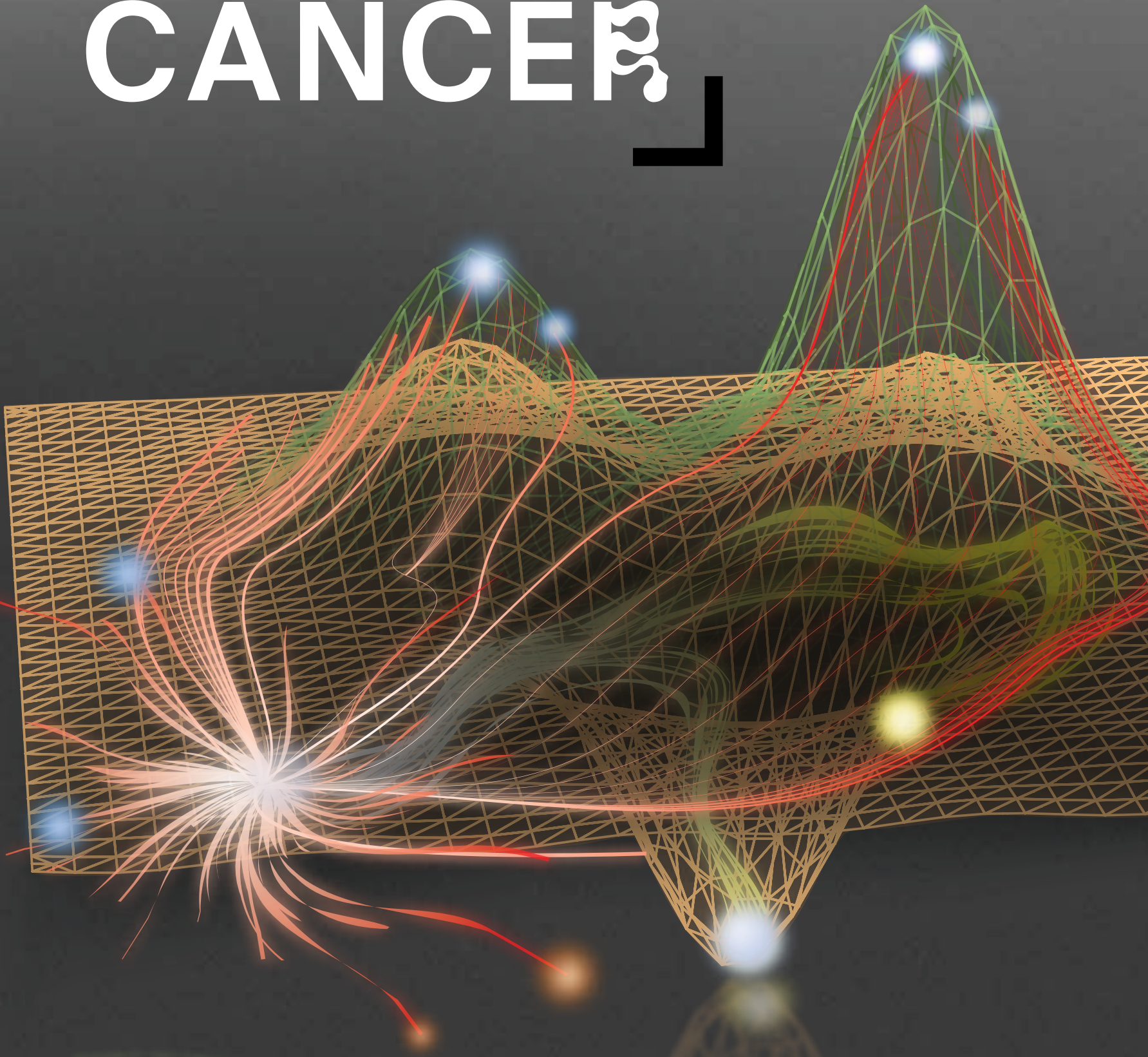
Cancers are shape shifters. A single tumor often features multiple varieties of wildly proliferating cells, with each variety undergoing genetic mutations. Chasing these moving targets, researchers tailor therapies that arrest—but only rarely vanquish—the disease.

However, momentum may finally be shifting in the quest for effective cancer treatments.

"For so long, therapy has been reactive," says Michael Hemann, who has joined forces with fellow MIT faculty member Douglas Lauffenburger to address this challenge. "What if we could instead steer tumors toward an outcome we know how to manage, or toward becoming better-behaving tumors?"

This is no wishful thinking. Hemann is professor of biology at MIT's David H. Koch Institute for Integrative Cancer Research, which has just celebrated its fifth anniversary. He and Koch Institute extramural faculty member Lauffenburger—the Ford Professor of Biological Engineering, Chemical Engineering, and Biology, and head of MIT's Department of Biological Engineering—have been collaborating on studies that suggest it is possible to predict and shape a cancer's unique trajectory, and to determine points along that journey when it may be especially susceptible to treatment.

Their work, in a field of research called systems biology, creates a finely detailed portrait of the complex evolution and drug responsiveness of certain kinds of cancer.

"Only by embracing and comprehending the complexity can you hope to come up with effective treatment," says Lauffenburger. "And we have the experimental tools to be as comprehensive about studying complexity as we want."

Hemann arrived at MIT in 2006 skilled in the latest methods for manipulating genes in living organisms. As a graduate student at Johns Hopkins University, and then as a postdoctoral fellow at Cold Spring Harbor Laboratory, he had trained to use viruses and RNA interference to grow specific cancers in mice. He more recently added CRISPR to his repertoire, an even faster technique for modifying the genome of living cells.

"We have an entirely new toolset for manipulating genetic systems *in vivo*," says Hemann. "We can now perform big genetic screens with mouse models, looking at lots of phenotypes [expression of genetic traits], introducing many changes at once to see how a tumor emerges or resists a cancer therapy."

These kinds of experiments generate reams of genetic data that require sophisticated analysis—an area that falls directly in Lauffenburger's wheelhouse. On the MIT faculty since 1995, Lauffenburger calls himself "half cell biologist, half engineer," and was prepared when "biology hit the omics era." ("Omics" refers collectively to the study of genes and proteins that comprise living organisms.)

With research interests in cancer and biomedical engineering, Lauffenburger devises computational strategies for capturing changes within complex biological systems from the molecular level up. By "creating conceptual frameworks," Lauffenburger says, he aims "to get the most power out of omics experimental methods."

"The unexpected can be transformational"

With their common interests and complementary skillsets, Hemann and Lauffenburger seem like an obvious research match. But they needed a well-placed nudge to forge a union. This was delivered in 2008 by Justin Pritchard PhD '12, then a graduate student of Lauffenburger's, who was intrigued by the cancer data flowing out of Hemann's lab.

"This situation is the epitome of MIT," says Lauffenburger. "It's the brilliant, fearless, creative graduate students who find connections between labs." They "facilitate our interaction in a deep way," adds Hemann. "Students are the glue that holds us together."

In the course of investigating how combinations of drugs worked on B-cell lymphoma, a type of blood cancer, Hemann had generated a very large data set. "In Mike's world, you can perturb hundreds to thousands of gene products," says Lauffenburger. "The issue is figuring out what's important to tumor biology."

Based on decades of experience treating patients, clinicians have discerned that some drugs in combination can achieve a kind of one-two punch against B-cell lymphoma. But the biological mechanisms behind their efficacy remained unknown. Pritchard realized that by using Lauffenburger's computational models, he could mine the giant data set for patterns of drug impacts, gleaning likely pathways of tumor susceptibility, and identifying which drugs worked best, and in what combination.

Pritchard's research "gave a multivariate genetic foundation" to a common clinical practice, says Lauffenburger, helping provide "a biological rationale for this kind of drug treatment."

This study, the basis for Pritchard's thesis and multiple journal articles, was the launching point for a series of collaborative ventures between Lauffenburger and Hemann—all facilitated by graduate students. It is a partnership that is taking both labs into new scientific territory, and breaking new ground in cancer research. As Hemann puts it: "In biology, the unexpected can be transformational."

The two laboratories began to zero in on what Hemann calls "one of the essential problems in cancer biology": tumor heterogeneity. While tumor cells start as single cells, they begin growing uncontrollably, and then differentiate into diverse subpopulations. There can be heterogeneity of tumors across patients with the same cancer, as well as heterogeneity within the same tumor.

Given such wild variation in a given type of cancer, how do researchers identify effective treatments, especially when the treatments themselves promote mutations and further drug resistance?

"Now we can stay ahead of the game"

Another joint graduate student, Boyang Zhao PhD '16, began to crack this puzzle. In Hemann's lab, he created heterogeneous lymphoma tumors in mice, and then tested these

tumors with single and combination drug therapies. Zhao used Lauffenburger's computational tools to analyze data comprised of 10,000 heterogeneous tumor compositions and their response to six drugs.

"The computational work allowed Bo to simulate an evolving mix of tumor cells, so he could predict the response of these heterogeneous cells to treatment," says Hemann. "This really moved us forward."

The team's focus on heterogeneity began paying off rapidly. Using mouse models of acute lymphoblastic leukemia, Zhao discovered that at an early stage of the evolution of the cancer, it developed an acute sensitivity to drugs that had demonstrated no previous efficacy in the treatment of this disease. "This is the awkward phase, the teen years, for the tumor, when it's hypersensitive to drugs," says Hemann.

This research suggests not only that modeling can predict optimal times for treating this leukemia, but that it might also be possible to dynamically modify cancers in order to sensitize them to therapy. "Now we can stay ahead of the game," says Lauffenburger. "We know at what point to hit the cancer with a new drug."

These findings, published in the March 24, 2016, issue of the journal *Cell*, have the potential to improve treatment for a range of blood cancers, including acute myeloid leukemia, with its diversity of genetic subpopulations, and others such as chronic myelogenous leukemia, where only patients with a specific genetic mutation find relief through a highly targeted drug regimen.

But the team's hybrid approach, combining genetic manipulation *in vivo* and powerful computational frameworks, has even broader potential. "We believe it could apply to any type of heterogeneous cancer, which really means any type of cancer," says Lauffenburger. "It leads us to a new world of drug screening," adds Hemann. "We can now determine a tumor's unexpected sensitivities, and find new compounds that have efficacy during the evolution of the disease."

While their work raises the possibility of rapid testing of new and more targeted cancer drugs, it also points to better application of current drugs. "If we could block the protective signals in some tumors that make them drug resistant, and find the best time to administer the drug, then current frontline chemotherapy could work better at lower doses," says Hemann. "Our big mission is to make therapies more effective and less toxic."

To that end, the researchers will be partnering with clinicians at local teaching hospitals. "One of our next proving grounds will be drug resistance in lung cancer," says Lauffenburger. This means expanding their collaboration: "We will be adding more students to our labs," notes Hemann.

It's a prospect both scientists relish. "Our interactions are multifaceted, with the science and personal dimensions all intertwined," says Lauffenburger.

"We know how to defer to each other's expertise, and this has allowed us to move in directions we never would have before," says Hemann. "As with any good relationship, you find a situation that endures because it's both productive and exciting." —Leda Zimmerman

The Chirp Heard Across the Universe

By the time it reached Earth, the chirp was far too weak to be detected by humans. But the Laser Interferometer Gravitational-Wave Observatory (LIGO) detectors heard it—first in Livingston, Louisiana, then seven milliseconds later in Hanford, Washington. For the first time, a century after Albert Einstein proposed his general theory of relativity, gravitational waves had been detected.

Researchers from MIT and CalTech, which jointly operate LIGO, announced their findings to the world on February 11, 2016. The breakthrough ushers in a new era of astrophysics. And for many members of the LIGO team it confirms an idea at the center of their life's work. In the weeks since the news broke, LIGO team members reflected on the discovery.

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Nergis Mavalvala PhD '97, the Curtis and Kathleen Marble Professor of Astrophysics and associate department head of physics, began working on gravitational wave detection in the 1990s as a graduate student at MIT.

"For the first time, we've been able to listen to the sounds that the universe has been transmitting to us from the beginning of time."

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David Shoemaker SM '80, MIT LIGO laboratory director and senior research scientist at the MIT Kavli Institute for Astrophysics and Space Research, briefed members of Congress on LIGO's significance.

"[LIGO] will allow us to work with other observatories using established technologies, such as radio, optical, and x-ray telescopes and satellites, to combine data from gravitational waves and traditional instruments. In this way we can test theories about fundamental components of the cosmos, such as neutron star matter and supernovae. We certainly also expect many surprises will be discovered and explained as we develop this new branch of astronomy."

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In the 1960s, Rainer Weiss '55, PhD '62, MIT professor emeritus of physics, conceived of the idea for LIGO as part of a teaching exercise, and spent decades moving the project forward.

"I feel an enormous sense of relief and some joy, but mostly relief. There's a monkey that's been sitting on my shoulder for 40 years, and he's been nattering in my ear and saying, 'Ehhh, how do you know this is really going to work? You've gotten a whole bunch of people involved. Suppose it never works right?' And suddenly, he's jumped off."

Sources, from top: *Boston Globe*; House Committee on Science, Space, and Technology; MIT News Office

The New Urban Narrative

**From Korea to Mexico,
Dennis Frenchman reshapes city
centers around technology**

Dennis Frenchman '76, MArchAS/MCP '76 is an urban designer who believes in creating value. Yet he doesn't only use bricks and boulevards to do it. "Value doesn't reside in buildings or real estate, alone," says Frenchman, associate dean in MIT's School of Architecture and Planning. "It resides in the story those things tell."

The stories that attract Frenchman usually involve technology, both obsolete and cutting edge. He has helped failing factory towns find new voices, and written compelling second acts for spent rail corridors and decrepit ports. As a master's student at MIT, Frenchman drafted a plan to transform the moribund textile city of Lowell, Massachusetts, into a national park, which was subsequently established. "Where some people saw derelict buildings and high unemployment, I saw a chance to recraft the narrative to focus on Lowell's significance to the American Industrial Revolution," says Frenchman. "A compelling narrative that would draw investments and create employment."

An expert on the application of digital technology to city design, Frenchman has planned viable city centers all over the globe—from Abu Dhabi, United Arab Emirates; to Guadalajara, Mexico; to Zaragoza, Spain—seeding them with media and technology clusters that fuel local economies, attract investments, and, most of all, draw and retain a critical mass of residents and businesses. The Digital Media City he designed in Seoul, South Korea—which served as backdrop for last summer's blockbuster film *Avengers: Age of Ultron*—employs more than 50,000 tech developers, gamers, coders, and telecom and television workers.

Frenchman is actively participating in a new project, Distrito Tec—an ambitious plan to create an urban tech cluster around the flagship campus of the Tecnológico de Monterrey in Monterrey, Mexico. One of Mexico's most affluent cities, Monterrey had seen its urban center depopulate and deteriorate as its territory expanded fivefold between 1980 and 2010. From 2008 to 2011 the city saw a sharp uptick in crime, and the area around the campus was no exception: two students were killed in crossfire near the campus gates. The campus had been closing itself to the community for decades.

"We realized we had made the area less secure by walling ourselves in," says Jose Antonio Torre, Director of Citizen Centered Urbanism at Distrito Tec. "Professor Frenchman advised us to connect with our neighbors, to be a part of a larger network involving the city, the region, and the world. That was how we the university could create value in the knowledge-based economy."

Launched in 2013 with an extensive neighborhood outreach, Distrito Tec aims to create a thriving collaborative environment between the Tecnológico de Monterrey, technology companies, and the Monterrey community—an ecosystem of research, innovation, and entrepreneurship that will create opportunity and value for all stakeholders. The Distrito Tec project has already yielded promising results. Several tech companies have expressed interest in moving in. Current investments from developers and businesses approach $700 million—about 20% of the $3.6 billion the project aims to attract over the next 15 years. While the physical transformation of the area may require as much as two decades, Torre and Frenchman believe the project can be self-sustaining as early as 2018. The Tecnológico is already moving to reconnect with the community, inviting neighbors onto the campus for cultural and social activities. Several buildings that are currently fenced off will be accessible from the street by the end of 2016.

The Distrito Tec project embodies a new type of urbanism. Where 20th-century city planning saw industry exiled from city centers to the periphery, 21st-century planning reverses the exodus, inviting knowledge-industry companies back to urban centers. More than a change of direction, the return of digital production workers and entrepreneurs into urban centers also signals a change of practice. "Until recently, we tried to revive urban centers through consumption," Frenchman observes. "We built mixed use developments that offered shopping and restaurants and theaters—opportunities to buy things and spend money. In the 21st century, we're designing viable centers around production. These will become places where people make things." —Ken Shulman

Above: Key concepts for the Distrito Tec project include a pedestrian-friendly transit corridor (red) and a "Silicon Calle" (blue) for research labs, tech firms, startup accelerators, and other contributors to Monterrey's innovation ecosystem. Below: Distrito Tec.

Digital Ocean

**Modeling the diverse world of phytoplankton opens up a predictive view of our own**

It's taken a few hundred thousand lines of code and the better part of a decade for Mick Follows, Stephanie Dutkiewicz, and their colleagues to conjure up an approximation of the global ocean inside their computers. These two MIT oceanographers are on a mission—called the Darwin Project—to know everything they can about phytoplankton, the tiny plants of the sea that produce half the oxygen that we breathe, underpin oceanic food webs, and are key players in the flow of carbon on our planet. (In fact, phytoplankton lock up a tremendous amount of carbon in the ocean that would otherwise be floating in the atmosphere.) To achieve their goal, Follows (associate professor in the Department of Earth, Atmospheric and Planetary Sciences) and Dutkiewicz (principal research scientist at MIT's Center for Global Change Science) want answers to questions about the growth and death of these micro plants, what characterizes the environments where they're found, and how different types of phytoplankton interact with one another.

"If we can describe this complicated system with mathematics with some predictive power," says Follows, "then we know we're understanding something essential about how that system works."

By their own admission, Follows is the dreamer and Dutkiewicz is the pragmatist. For instance, when considering how many types of phytoplankton to include in their model, Follows suggested hundreds. Dutkiewicz countered with six. They've settled on 51, and the sizes of those types span nine orders of magnitude—equivalent to the difference in scale between a mouse and Manhattan.

All these kinds of phytoplankton aren't just ingredients in the Darwin Project's hard drives. Dutkiewicz says, "Trying to understand the how and why of diversity is at the heart of everything we do."

When they compare what the model predicts to actual data gathered by ships,
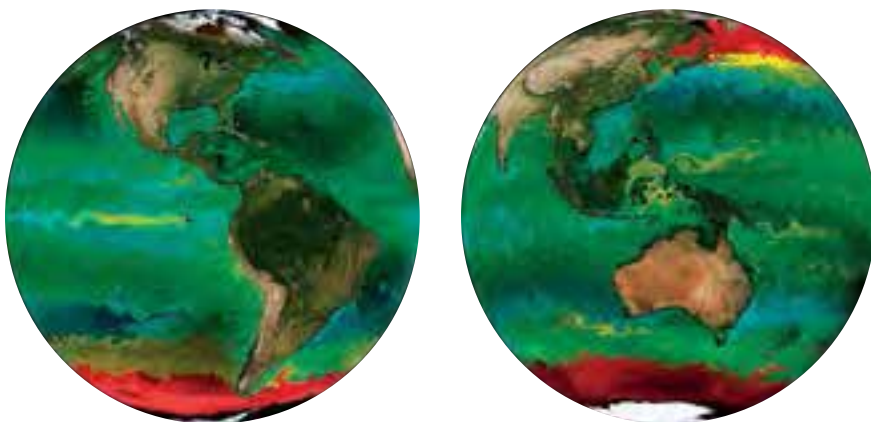
Visualizations generated by the Darwin Project, led by Stephanie Dutkiewicz and Mick Follows (above right), reveal the dynamic hidden world of phytoplankton.

PHOTO: KEN RICHARDSON

satellites, and lab experiments, it checks out. "It's confirmation of our understanding reduced into a set of equations," says Follows. The model captures the behavior of both the phytoplankton and the ocean they inhabit. This means it can be used to project what might happen in the future—during an El Niño year, say, or 100 years from now as our global climate continues to change.

Leading a team of a dozen MIT researchers, plus a handful of collaborators from universities around the world, Follows and Dutkiewicz have used their digital ocean to understand all sorts of things. Their investigations range from the geographic distribution of biodiversity in general and the various types of phytoplankton in particular, to where and how fast nitrogen gas is being incorporated into certain kinds of phytoplankton (a process that helps sustain entire food webs); and from how phytoplankton that occupy such a vast range of sizes can coexist, to how the physical movement of water on the planet influences the biology it contains.

The computer simulations of the Darwin Project have produced stunning visuals: some, for example, depict the Earth with darkened continents surrounded by an ocean swirling with color and churning with movement and life. According to Dutkiewicz, the visualizations have been "incredible outreach tools," allowing both scientists and non-scientists to see the ocean in a new way. They've been featured in displays at the San Francisco Exploratorium and the planetarium at the Museum of Science and Industry in Paris. "They're really beautiful to watch," Dutkiewicz says. "You get a sense of how dynamic the ocean is and how dynamic the phytoplankton communities are."

As the Darwin Project evolves, it grows increasingly complex. Follows, Dutkiewicz, and their colleagues have started incorporating into the code representations of ocean bacteria, seafaring viruses, and yet more diversity of phytoplankton and the organisms that eat them. By continuing to refine and improve their simulations, they seek to deepen our understanding of marine ecosystems. And if one day these equations are capable of tracing out the living contours of the ocean, we'll have a powerful tool for understanding our future—both at sea and on land. –Ari Daniel PhD '08

MIT (🌍)
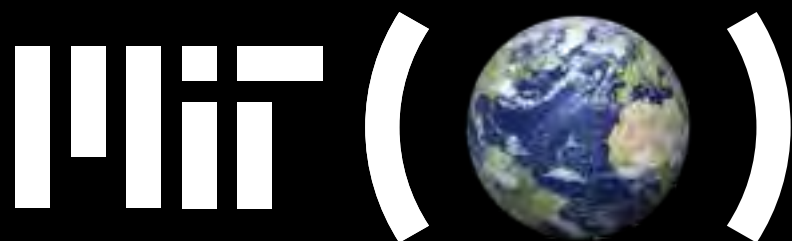
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Discovery Science

Basic science research at MIT has led to the discovery of the first human cancer gene, the first experimental confirmation of the existence of the quark, and the first chemical synthesis of penicillin. Yet often, with basic research, it is only when the discoveries are in hand that we begin to recognize their world-changing applications. The challenges posed by the 21st century are formidable and intriguing—and MIT is uniquely capable of translating scientific breakthroughs into practical solutions.

PHOTO: JOSÉ MANDOJANA

Health of the Planet

Global challenges around issues of environment and sustainability demand society's immediate attention. MIT is aligning its capabilities to lead and mobilize the effort to understand and address these challenges. Our cross-disciplinary initiatives and research activities around energy, the environment, and water and food start at home, with the development of a more sustainable campus, and extend to all corners of the world. Our talented faculty and students forge solutions with sweeping positive consequence and MIT is poised to lead in ensuring a healthy future for our planet and for humankind.

PHOTO: SARAH DAS (WHOI)

Human Health

Advances in science and engineering have vaulted us into an exciting age of health care. Yet infectious diseases, age-related disorders, and rising health care costs are among the major challenges facing humanity. At MIT, we are deeply committed to improving all elements and aspects of human health. We're convinced that the advances humanity needs most will emerge from the kind of creative, unconventional collaborations that are this Institute's hallmark. MIT has the unique capabilities, partnerships with hospitals and industry, and critical mass necessary to make bold strides in prevention, diagnosis, and treatment, and to develop ideas rapidly from bench to bedside.

PHOTO: LEN RUBENSTEIN

Innovation and Entrepreneurship

At MIT, innovation embodies the integration of theory and practice, art and science, thinking and making—the rich intersection of "mind and hand" in our motto. In fields as varied as genomics, economics, and robotics, MIT has consistently reframed problems as opportunities and transformed opportunities into impact. While the global innovation economy that shaped our history is changing, we remain committed to creating solutions faster and more effectively at every scale, and our students remain committed to making a difference in the world. At MIT, we have the power to engineer ambitious new innovation ecosystems in Massachusetts and around the world that are suited to our times and our students.

PHOTO: DOMINICK REUTER

Teaching, Learning, and Living

At MIT, education is at a moment of reinvention. We are exploring new avenues in the science of learning—and reaching for a greater understanding of how people learn at all levels, from pre-K–12 to lifelong students. In our classrooms, residences, and maker spaces, we are reinvigorating our traditional practices of making and doing while accelerating pedagogical innovation through digital tools and experiential education. With programs and facilities that support our students in all aspects of their lives, we are enriching and expanding our campus living and learning experience. And through digital learning efforts like MITx and OpenCourseWare, we are continuing to provide quality educational opportunities to all those with the drive and talent to seize them.

PHOTO: BEN BOCKO

The MIT Core

MIT has long been a powerful magnet for brilliant minds from across the globe. But attracting top talent requires more than the promise of an exceptional community. Students need to know they will have the resources to focus on their passions, and faculty need to know they will have support for their game-changing ideas. Undergraduate financial aid, graduate fellowships, reinvigorated residential spaces, and faculty professorships are crucial to ensuring MIT can continue to draw and nurture outstanding people. And the entire MIT community requires the education, research, and innovation facilities that will allow it to collaborate, flourish, and realize its exceptional potential.

PHOTO: FCB981/ CC BY-SA 3.0

Reimagining the MIT Campus

This spring, MIT marked the centennial of its transformation from Boston outpost to Cambridge icon. The festivities culminated in May with "Moving Day," a community parade, pageant, and floating spectacle. Attendees had occasion to note how much the face of the campus has developed and altered over the past 100 years—yet how its distinguishing features have endured. As MIT launches the Campaign for a Better World, it is preparing its campus for another century of dynamic use, and creating new spaces that will enable this community to reach the Institute's bold goals.

One of the campus's network of original buildings has just emerged from a renovation that makes it a fitting 21st-century headquarters for the MIT Department of Mathematics. Building 2, part of the stately "Main Group" designed by architect William Welles Bosworth 1889, reopened in January and has been renamed the **Simons Building**, in recognition of the generosity of James H. Simons '58 and Marilyn Simons. Led by MIT alumna Ann Beha '75, principal at Ann Beha Architects, the renovation aimed to restore antiquated infrastructure and create spaces that befit a modern academic enterprise. The work comprised detailed restoration of the limestone façade; reconfiguration and modernization of

classrooms, offices, and collaborative spaces, such as a newly expanded Math Commons; and the addition of a fourth floor.

An essential factor in the overall reimagination of the MIT campus is the expansion of facilities that allow the community to create, build, prototype, and tinker. Prominent among these will be a state-of-the-art innovation space planned for the historic **Metropolitan Warehouse**. Having stood sentinel, since 1895, to the changing landscape at the intersection of Massachusetts Avenue and Vassar Street, the imposing brick landmark is now slated to become a central destination for MIT students eager to turn their bright ideas into tangible inventions.

With enrollment in MIT's Theater Arts program booming, MIT has kicked off the transformation of a former warehouse at 345 Vassar Street that will consolidate all of the program's currently dispersed activities under a single

MIT is preparing its campus for another century of dynamic use, and creating new spaces that will enable this community to reach the Institute's bold goals.

An essential factor in the overall reimagination of the MIT campus is the expansion of facilities that allow the community to create, build, prototype, and tinker.

roof. Scheduled for completion in 2017, the new home for MIT Theater Arts (dubbed **W97**) will include rehearsal spaces, design and faculty studios, offices, costume and scene design shops, and dressing rooms. Its centerpiece will be a flexible two-story performance space that can be reshaped for each production, and that will accommodate a variety of uses. Along with maximizing the creative power of MIT's theatrical activities, sustainability is a priority of the project, with the goal of achieving LEED Gold sustainability certification.

High-tech prototyping facilities are a defining feature—along with state-of-the-art clean rooms, and fertile spaces for education and collaboration—of **MIT.nano**, the new 200,000-square-foot center for nanoscience and nanotechnology taking shape at the heart of the campus. Scheduled for occupancy in 2018, MIT.nano will enable faculty in departments across MIT—more than 20% of the Institute's researchers—to synthesize and manipulate molecules with breathtaking precision, and to speed their discoveries to impact in fields as wide-ranging as computing and communications, energy, health, and manufacturing.

Looking east, plans for MIT's developments in **Kendall Square** continue to move forward in the design phase. Six new buildings, comprising nearly a million square feet in the midst of this burgeoning innovation hub, are planned to rise on what are now five MIT-owned parking lots. These will include three buildings for commercial office and laboratory use, two for housing, and one for academic use. The plan also includes nearly three acres of new and repurposed open spaces, ground floor retail, and a new home for the MIT Museum. Provost Martin Schmidt SM '83, PhD '88 has described the project as a "unique opportunity to expand our residential community, infuse new vibrancy into Kendall Square with retail and public gathering spaces, create space for innovative research and development activities, introduce a new gateway to MIT, and create a vibrant crossroads that will connect us more closely to the Cambridge community."

(↗)

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Kendall Square rendering by Encore; courtesy of Elkus Manfredi Architects

Why We Give

A gift to MIT may be based on a deep personal connection to the Institute, or to the questions and problems it strives to answer and solve. Gifts may be directed toward shaping students' educational journeys, bolstering a line of research, or enabling the Institute to respond nimbly to shifting needs and opportunities. Every donor to MIT has a stake in this special community and the extraordinary work it does. And every gift to MIT—no matter the motivation or the size—has something in common: it is helping to build a better world.

"Education is the great equalizer. It doesn't matter who your parents are, what they do for a living, how much money they have, what race, ethnicity, gender, or religious background you come from—if you have a great education, you can do whatever you want and follow your dreams."
Lydia Kennard MCP '79

"I was going to MIT no matter what, but I hadn't realized that I was actually relying on the generosity of an individual to make it possible. As a junior, I had an email exchange with the donor. I decided right then that someday I would create the same opportunity for someone else."
Mike Evans '99, MEng '00

"With MIT focused on solutions for water, food, and the health of the planet, we want to stay involved and support programs that send MIT students into the world where they can do the most good."
Karen '85, SM '87 and Perry '85, SM '87 Ha

"MIT innovates better than any other university in the world. We wanted to give back in a way that facilitates MIT's leading role in birthing new companies."
Colin '89, SM '91 and Erika '04 Angle

"Ultimately, it is research that raises the quality of life, and if you love science and discovery and people, then you should support basic research."
Jonathan Rothberg

"We want MIT to continue to thrive as a force for US competitiveness and to continue to transform the world....We love the idea of giving back to the Institute that helped us get to where we are today."
Mick '87 and Tiffany Mountz

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TOGETHER, WE CAN MOVE MEGALITHS.

With a few ropes and lots of savvy, MIT students raised a 2,000-pound megalith in Killian Court for a cross-disciplinary architecture studio— proving that with combined perspectives and smart solutions, there's no problem too big to budge.