CRITICAL MAKING COMES TO CAMPUS

DESIGNING, PROTOTYPING AND BUILDING IN BERKELEY'S NEW INVENTION LAB

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"Thirty seconds." Students are drawing frantically as EECS and new media professor Eric Paulos stands at the front of the class keeping time.

"Ten seconds." Then after a long pause, he says, "Eight second bonus." The room, only moments ago solemn with deadline tension, fills with laughter.

Time is up. The partners show the caricatures they have drawn of each other. The results range from recognizable to deplorable, but the actual drawings are not the point.

"I don't know if you were paying attention, but people were giggling in the middle of the exercise," Paulos says. "And play," he adds, "is the greatest resource in a creative economy."

It is the first day of a new class called Critical Making: Materials, Protocols and Culture, held in the recently opened Invention Lab on the ground floor of Sutardja Dai Hall. Critical Making is taught studio-style and combines lectures, assignments (called "provocations"), design work sessions and student critiques. The class is listed as a computer science course, but today, students arrived from all across campus—graduates, undergraduates, urban planners, artists, anthropologists, engineers, statisticians and filmmakers. Attracting a range of students from different backgrounds to a corner of campus usually dominated by engineers was Paulos's intent.

"Students are going to have an understanding of how to collaborate across disciplines while respecting and appreciating the viewpoints, values and concerns of others about a design," Paulos says. "I fundamentally believe that this is the future of the practitioner. They will have to know how to co-create things."

Before the class started in January, news of the opportunity to hack, build and make spread quickly. "My friends know I am interested in design," says Brittany Cheng, a third-year EECS student. "Somebody forwarded me a link, saying, 'Hey, this class is happening next semester, and it looks really cool.' Then I told a couple of my friends, and we all signed up for it."

To be an enterprising engineer in today's ecosystem of open-source hardware, crowdsourcing and digital media requires an understanding of multiple tools, materials, systems and ways of expressing ideas. "I want to be building things on my own, as opposed to working at a big corporation and plugging in little chunks of code," says Aatash Parikh, a third-year EECS major. "I basically want to be working on my own projects, creating things my own way."

The desire to control the entire creative process from initial concept to finished construction is exploding in what Paulos calls a shift from proprietary innovation to populist innovation. Collectively, the current surge of hands-on creativity is often called the Maker Movement. The maker label started gaining traction in 2005 after Dale Dougherty, an editor at tech book publisher O'Reilly Media, started *MAKE* magazine. A year later, O'Reilly Media held the first Maker Faire in San Mateo, California. Tens of thousands of people showed up to share ideas and inventions.

"Making is fun, satisfying and rewarding," says Dougherty. "It maps to people's goals. They might say, 'I want to do these things, learn these things. I enjoy doing them. At a cultural level it feels like I am contributing to something.' The sense of giving and creating is empowering."

The design-centric, collaborative culture that underpins the Maker Movement is more than just an identity—it is also influencing manufacturing, commerce and business. In his new book *Makers: The New Industrial Revolution*, Chris Anderson, the former editor-in-chief of *Wired*, writes, "Some of the biggest companies in the world of professional product design and engineering are now shifting their focus to the emerging maker market. Like IBM a generation ago, which went from corporate mainframes to personal computers, they are recognizing that their futures lie with regular folks. They are pivoting from professionals to everyone."

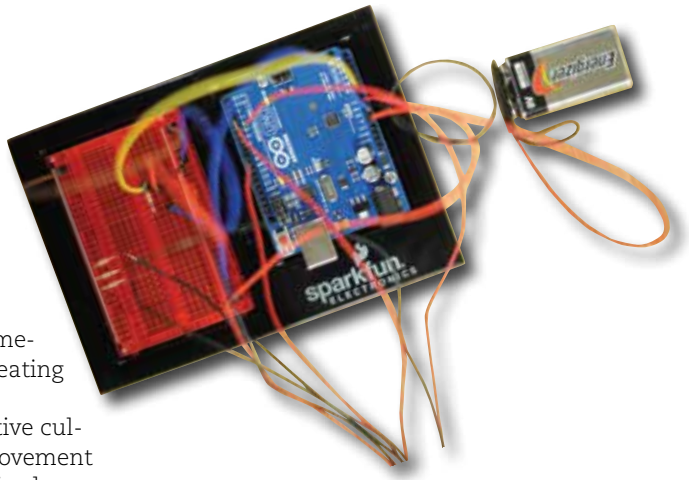
Another important part of the maker ethos is a reconnection to the creativity inherent in youthful curiosity. At the end of the first class, Paulos passes out material to complete the homework. Each student receives a sandwich-sized Ziploc bag. Along with some standard-issue equipment—some colored LED lights, a battery connector and a few short wires—each bag contains two colored balls of play dough that Paulos made in his kitchen. The green ball conducts electricity; the yellow does not. The assignment entails combining the materials with found items to create a new interactive, electrical object.

"Play with it over the weekend," says Paulos. "The idea is to think about this and use new materials. Your friends will probably say, 'Wait, I got books on the first day of class and you got play dough?'"

Hands on

Instead of a textbook, Paulos's students purchased Sparkfun Inventor kits, which arrived in time for the beginning of the fourth class. The kits come in bright red cardboard boxes about the size of a cigar box. Inside each student's box is an instruction manual, a colorful nest of short jumper wires, LEDs, a small DC motor, a few transistors, a breadboard and under it all, the hub of the kit: an Arduino Uno R3 micro-controller.

Arduino boards come in various sizes and are foundational to most modern electronic maker projects involving



robotics, sensors or communication. The software to power the controllers is all open-source. New lines of Arduino code and novel project ideas are shared and traded freely among enthusiasts.

With a project kit laid out in pieces in front and his workspace projected on the wall of the lab for a demo, Paulos says to the class, "We are going to do something really simple: set up a switch, bring in power and a ground. In between the two, I'm going to put in a red LED and construct a circuit." The students are watching and sifting through their new kits. Eventually, Paulos works up to plugging in the Arduino and making the light blink at regular intervals.

Some of the students start asking technical questions about transistors. And then one student asks, "Is there any risk of us blowing these things up?"

"All good questions," Paulos says.

Paulos started exploring the concepts that would eventually become the core of the critical making class while he was a Berkeley EECS graduate student in the mid-1990s. At the time, he was interested in robotics, but he was also experimenting with the emerging field of new media. Paulos combined these two interests in one of the first Internet-based telepresence projects, called Personal Roving Presence (PRoPs). Part of the project required developing the technology that allowed people to have a physical presence in one place and a virtual presence in another. For the other aspect of the project, Paulos created situations that forced people to interact with a telepresence device, which was intended to prompt debate about the ethical and social issues that might surface with adoption of remote robotic systems and human relationships.

"I was interested in designing, measuring, studying and presenting a peer-reviewed, scientific document to describe how technology will play a role in human connectivity," Paulos says. "At the same time, I was also interested in engaging people outside of traditional computer

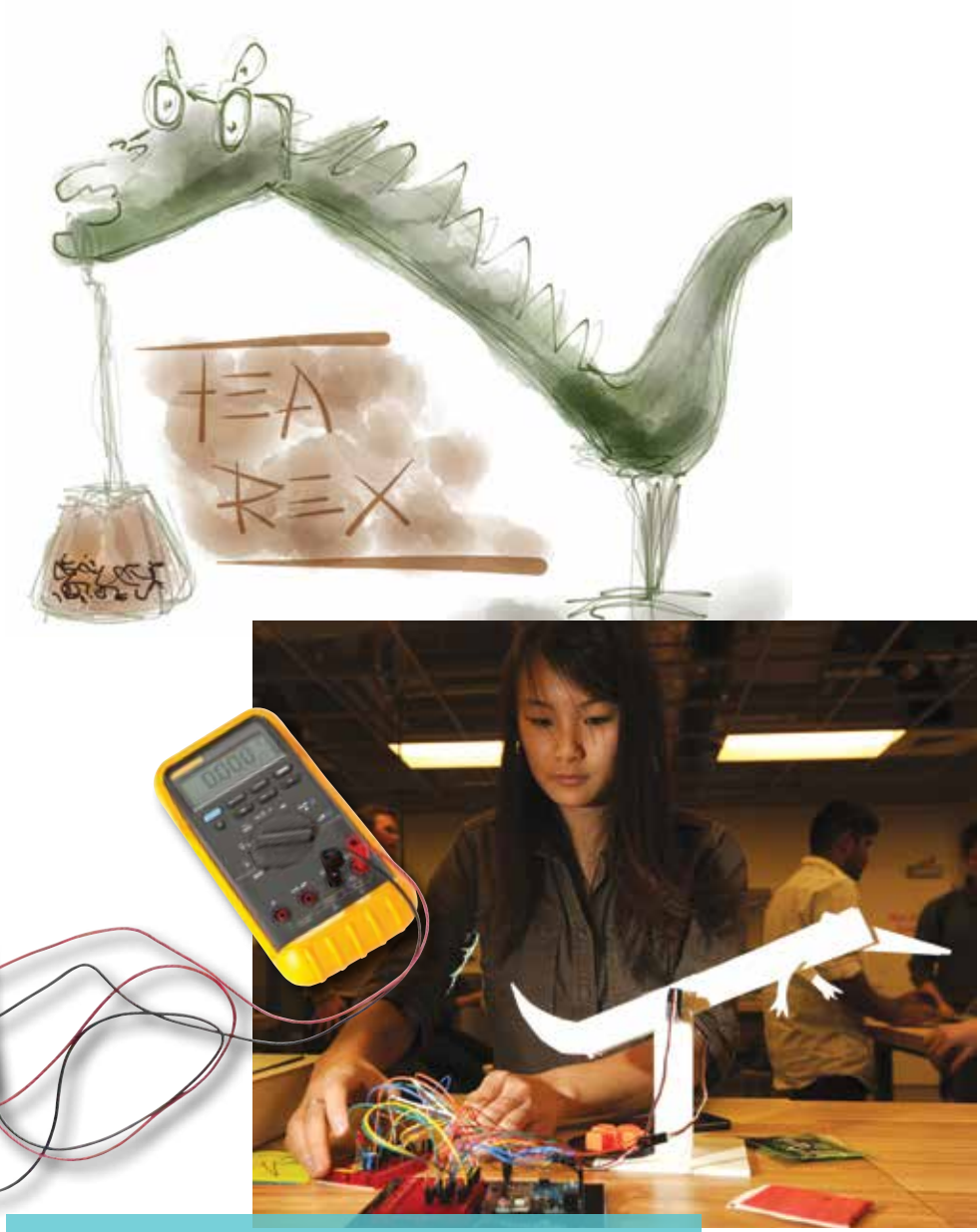
science about the dilemmas and challenges around telepresence."

After graduate school, Paulos founded Urban Atmospheres, a research group at an Intel-sponsored lab at Berkeley. As with the telepresence project, Paulos and his colleagues found themselves investigating emerging computing technologies in 2002. One Urban Atmospheres project looked at interactive experiences between people, places and objects using early mobile phone platforms.

By 2006, Paulos joined the faculty at Carnegie Mellon University (CMU), in Pittsburgh, where he directed the Living Environments Lab. His research kept evolving as mobile devices continued to mature, and he started investigating how citizen scientists were using sensor technologies embedded in smartphones. While at CMU, Paulos also ran an energy-focused project, which, like his telepresence work, had multiple layers. In research backed by the National Science Foundation, his team built simple devices that were capable of scavenging and using energy on a small scale.

As an extension of the project, Paulos built devices that harvest energy from public places in an award-winning project called "Energy Parasites." The energy-scavenging devices were designed to prompt discussion about energy ownership. They were part of the international new media show Ars Electronica and will be exhibited in Belgium and Spain.

Paulos returned to Berkeley as a faculty member in the fall of 2012. He plans to continue investigating the interactions between people and technology, as well as the implications of emerging DIY technologies. "We look at technology, society and the milieu of culture, and we posit a future vision. Then, through the course of studies and formal investigations, we end up making objects that critically address those issues," Paulos says about the current work of the research group he advises. "That's the process, and it's very much in line with what is happening in the critical making class."



Third-year EECS major Brittany Cheng makes some adjustments to Tea-Rex, a device programmed to steep the perfect cup of tea. Motors connected to an Arduino controller raise and lower the neck of the apparatus while making use of time and temperature sensors.

Making space

Clustered in the middle of the Invention Lab are a half-dozen wooden-topped work benches surrounded by tall stools. Along the perimeter of the room are metal shelves containing hand tools and electronics gear, various stashes of materials like foam core and acrylic, and digital fabrication tools including a 60-watt laser cutter and a 3D printer the size of a dorm refrigerator.

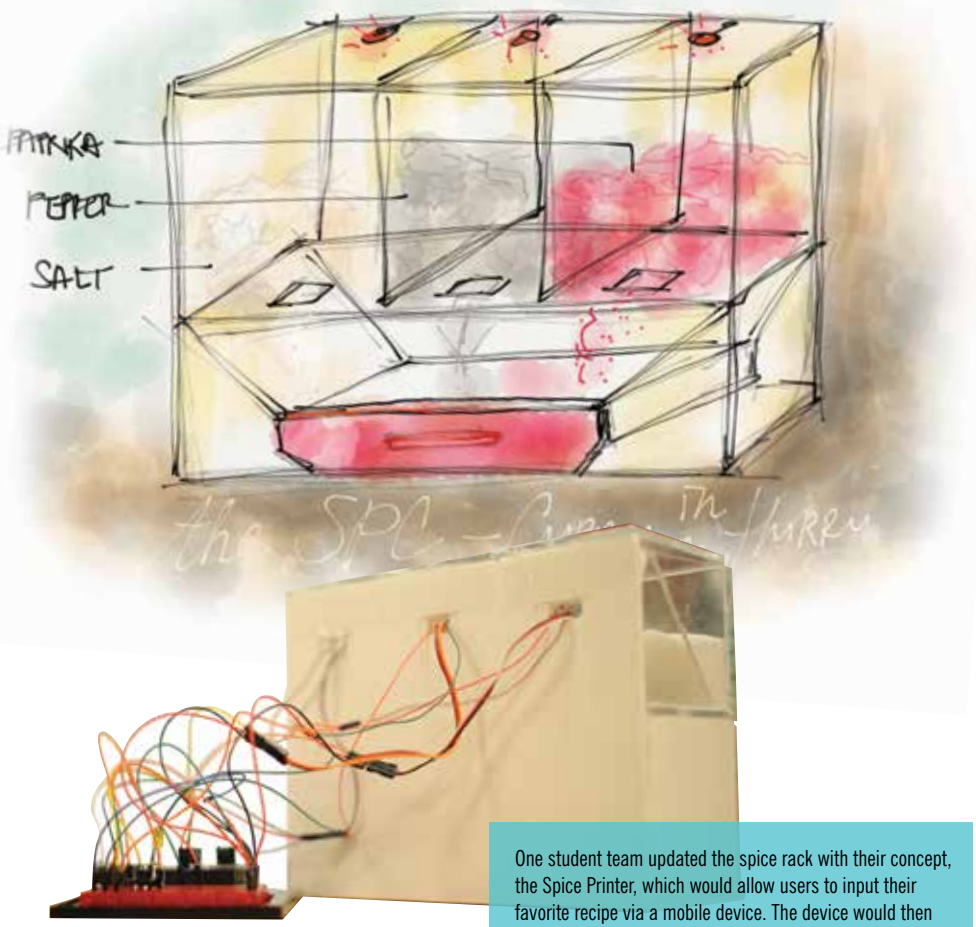
The space opened at the end of 2012 and is already filling up with examples of student work. "The Invention Lab is a really cool space. Just having all those tools there and available and to come in and make stuff and print things whenever the lab is open is pretty nice," says Cheng. "The things I learn in my other classes are more like theory or concepts. It is very rare that I get to do something that involves a little bit of programming, a little bit of circuits, a little bit of cutting things with X-acto knives and a little bit of putting things together."

The idea of carving out creative spaces that combine the best of a computer lab, art studio, workshop and other collaborative spaces, like the Invention Lab, is something that also resonates with *MAKE* magazine's Dale Dougherty, who is working to create similar labs in 15 Bay Area high schools. "Sometimes I feel like the real win is creating spaces where the people are visible, the work is visible, and the tools are visible. The learning in making comes from this idea of iterative process, which leads to critical making. Enjoying that process and enjoying the learning is important."

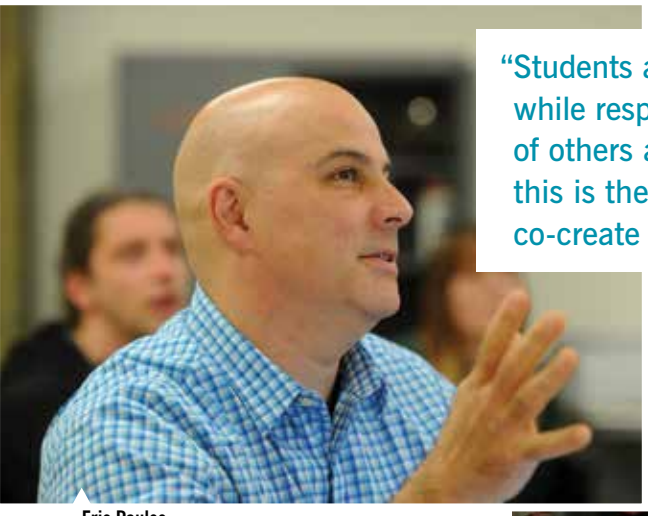
Parikh, the third-year EECS student, underscores the value of maker space on campus: "To be honest, I feel like this is a perfect class for people who are just getting into engineering. I think that all freshmen should take it. I've talked to friends in and outside of the class, and they have all said this is what they thought they would be doing when they signed up for engineering. We are actually building things," he says.

Five weeks into the class, the first critique has arrived. Student projects are lining a table at the front of the lab. The assignment, aptly named "Counter Culture," asked students to work in groups to create a novel device for the kitchen. Some teams are tinkering with last-minute details before their presentations. Based on the discussions in the lab, it is obvious that some of the more abstract critical design concepts are becoming concrete, just as the prototyping and digital fabrications tools are becoming more familiar.

"I like the critical-making terminology because it is obviously a play on critical thinking," Paulos says, "It's a deeper reflection about not just making stuff, which is interesting, but being critical about it." BE



One student team updated the spice rack with their concept, the Spice Printer, which would allow users to input their favorite recipe via a mobile device. The device would then "print" properly measured amounts of seasonings from the storage container to an awaiting tray. The printer would also track spice levels and send alerts when running low.



Eric Paulos
Assistant professor, EECS

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The studio-style class attracts students from a wide range of academic disciplines, including computer science, architecture and media studies. The first major assignment, called "Counter Culture," asked teams to program a microcontroller and build a device addressing a kitchen-related issue.