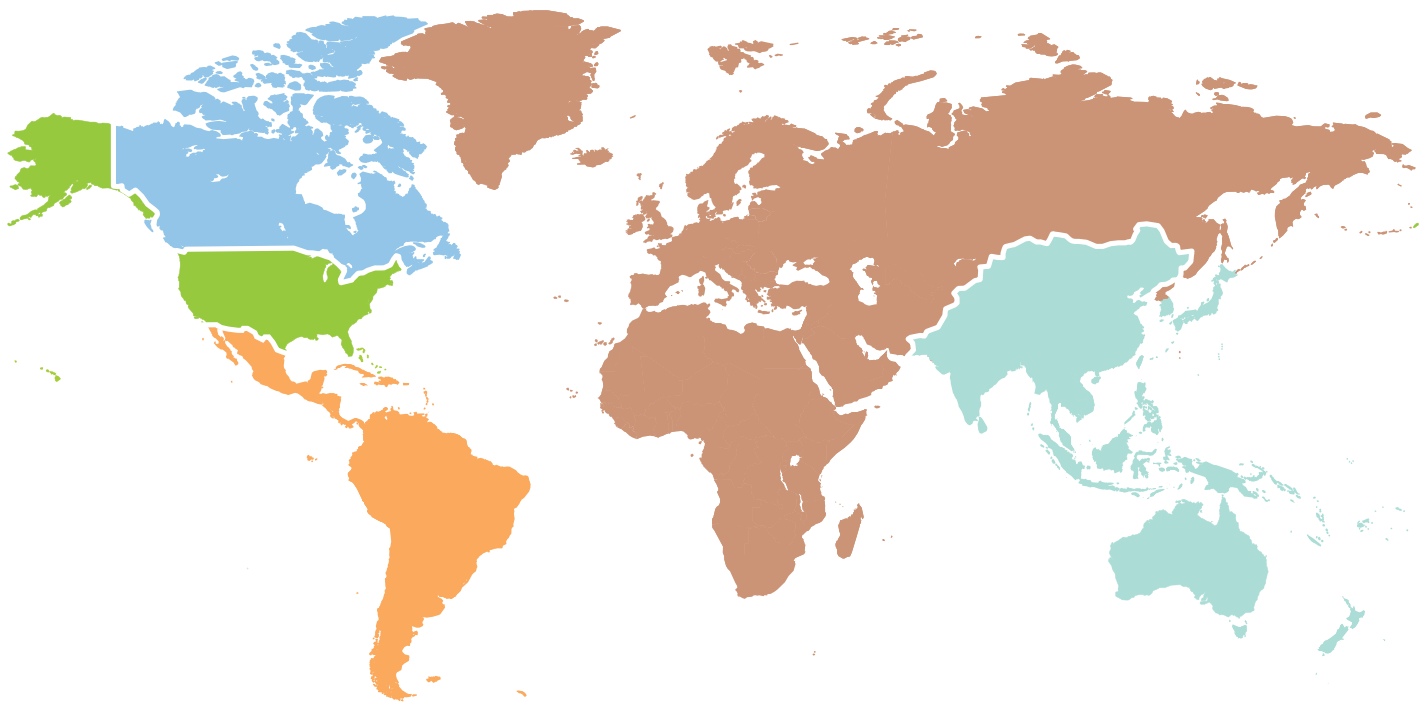


the institute

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*The State of
Engineering
Education*





REGION NEWS

REGION 1 NORTHEASTERN UNITED STATES

- **Connecticut Section** forms IEEE Young Professionals (YP) affinity group.
- Student branch formed at **Curry College, Milton, Mass.**
- Student branch at **Tufts University, Medford, Mass.**, forms IEEE Power & Energy Society chapter.
- Student branch at **New Jersey Institute of Technology, Newark**, forms IEEE Engineering in Medicine and Biology Society chapter.
- **Providence (R.I.) Section** forms IEEE Computer Society chapter.

REGION 2 EASTERN UNITED STATES

- **Northern Virginia Section** forms IEEE Women in Engineering (WIE) affinity group.
- **Columbus (Ohio) Section** forms IEEE WIE affinity group.
- Student branch formed at **Elizabethtown College, Pennsylvania.**
- Student branch at **Shepherd University, Shepherdstown, W.Va.**, forms IEEE WIE affinity group.

REGION 3 SOUTHEASTERN UNITED STATES

- **Huntsville (Ala.) Section** forms IEEE Life Members (LM) affinity group.
- **Miami Section** forms IEEE WIE affinity group.

REGION 4 CENTRAL UNITED STATES

- Student branch at **Purdue University, West Lafayette, Ind.**, forms IEEE Engineering in Medicine and Biology Society chapter.
- **West Michigan Section** forms IEEE LM affinity group.

REGION 5 SOUTHWESTERN UNITED STATES

- Student branch formed at **University of Arkansas, Fort Smith.**
- Student branch at **Missouri University of Science and Technology, Rolla**, forms IEEE Industry Applications Society chapter.

REGION 6 WESTERN UNITED STATES

- **San Diego Section** forms IEEE Industry Applications Society chapter.
- Student branch at **University of California, Berkeley**, forms IEEE Photonics Society chapter.
- Student branch at **University of California, Los Angeles**, forms IEEE WIE affinity group.

REGION 7 CANADA

- **Montreal Section** forms IEEE YP affinity group.
- **Vancouver Section** forms joint chapter of IEEE Engineering in Medicine and Biology and IEEE Signal Processing societies.
- Student branch at the **University of Calgary** forms IEEE WIE affinity group.

REGION 8 EUROPE, MIDDLE EAST, AND AFRICA

- **Bahrain Section** forms IEEE YP affinity group.
- **Benelux (Belgium, the Netherlands, and Luxembourg) Section** forms IEEE LM affinity group.
- Student branch formed at **International Burch University, Sarajevo, Bosnia and Herzegovina.**
- Student branch formed at **Frederick University, Nicosia, Cyprus.**
- Student branch formed at **Al-Manar University of Tripoli, Lebanon.**
- **Portugal Section** forms IEEE Instrumentation and Measurement Society chapter.
- **Romania Section** forms IEEE WIE affinity group.
- Student branch at **Effat University, Jeddah, Saudi Arabia**, forms IEEE Robotics and Automation Society chapter.

REGION 9 LATIN AMERICA

- Student branch formed at **Universidad Tecnológica Nacional, San Rafael, Argentina.**
- Student branch formed at **Universidade Federal de Santa Maria, Brazil.**
- Student branch at the **University of Costa Rica, San José**, forms IEEE WIE affinity group.
- Student branch at **Universidad Autónoma de Guadalajara, Mexico**, forms IEEE WIE affinity group.
- **Puerto Rico and Caribbean Section** forms IEEE WIE affinity group.

- **Uruguay Section** forms IEEE LM affinity group.

REGION 10 ASIA AND PACIFIC

- Student branch at **Stamford University Bangladesh, Dhaka**, forms IEEE WIE affinity group.
- **Beijing Section** forms IEEE Vehicular Technology Society chapter.
- **Chengdu (China) Section** forms IEEE YP affinity group.
- Student branch formed at **University of the South Pacific, Suva, Fiji.**
- **Pune (India) Section** forms IEEE Education Society chapter.
- Student branch at **Curtin University, Sarawak, Malaysia**, forms IEEE Industry Applications Society chapter.
- Student branch at **Singapore University of Technology and Design** forms IEEE Signal Processing Society chapter.
- Student branch formed at **Sabaragamuwa University of Sri Lanka, Balangoda.**
- Student branch formed at **Tra Vinh University, Vietnam.**

SEND US YOUR NEWS

We announce the formation of new groups once they've been approved by IEEE Member and Geographic Activities. To send us news of student branch events and competitions, WIE or preuniversity outreach efforts, or other IEEE group activities, use the form on the Region News page: <http://theinstitute.ieee.org/region-news>.

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BRIEFINGS

IEEE Day Is 4 October

MEMBERS AROUND

the world are organizing special events to celebrate IEEE Day on 4 October, including technical talks, panel discussions, and humanitarian projects. The day commemorates the anniversary of the 1884 meeting in Philadelphia when members of the American Institute of Electrical Engineers, one of IEEE's predecessor societies, gathered for the first time to share technical ideas. Last year, 657 celebrations took place.

Visit <http://www.ieeeday.org> to add your event to a world map and see what other groups are planning.

Contests are held to determine the best photos and videos taken at IEEE Day celebrations. Each IEEE organizational unit that submits a winning photo and/or video wins a cash award. The IEEE Day website will display the winning entries later this year.

To commemorate the celebration, IEEE is offering a US \$30 discount on dues for new members who join between 2 and 8 October. (The offer does not apply to student or graduate student memberships.) New members should enter the promo code IEEEEDAY16 at <http://www.ieee.org/join> to receive the discount. —Amanda Davis

GlobalSpec Is Now Part of IEEE

IEEE ACQUIRED GlobalSpec and its Engineering360 platform from IHS in April. GlobalSpec is a search engine and a leading source of news, data, and analytics for the engineering and technical communities. The platform has more than 8 million registered users. Renamed IEEE GlobalSpec Inc., the for-profit subsidiary and its 145 employees are located in East Greenbush, N.Y., near Albany. IEEE's former chief marketing officer, Patrick D. Mahoney, was appointed as GlobalSpec's president and CEO.

IEEE GlobalSpec is used to research, compare, and price components. Its database has about 95 million technical documents, 200 million data sheets, 200,000 suppliers, 82,000 product announcements, 63,000 catalogs, and more than 800 specification guides. The material is aimed at industry-based engineers, technical professionals, manufacturers, distributors, and service providers involved in technical research, product design, and purchasing.

Users can research industry standards and patent information, find reference materials, and review product data sheets. The company also offers webinars and online forums where technical professionals collaborate, plus a full suite of marketing tools and products. "IEEE GlobalSpec delivers an unparalleled depth and

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Meet the CEO of edX, the Online Learning Platform 18

ONLINE

at theinstitute.ieee.org

STUDENT GRANTS See what the IEEE Foundation has to offer.

IN MEMORIAM IEEE mourns the loss of three of its members.

quality of highly relevant content critical to the worldwide technical community," says IEEE Executive Director E. James Prendergast.

"IEEE GlobalSpec is destined to drive new research efficiencies and productivity opportunities for academic and corporate users by harnessing powerful insights and expert analysis—from specifications to expert marketplace analysis." —Kathy Pretz

Sections Congress Coming in August

THE 2017 IEEE Sections Congress is scheduled for 11 to 13 August at the International Convention Centre in Sydney. The IEEE Member and Geographic Activities Board is partnering with Region 10 (Asia and Pacific) to host the event.

Held every three years, the congress provides IEEE volunteers and leaders of IEEE regions, sections, subsections, chapters, geographic councils, and affinity groups with the opportunity to network and discuss ways to promote and increase members' participation in IEEE activities. The congress also develops recommendations that it submits to the IEEE Board of Directors to help guide the direction of IEEE.

Registration begins in February. To learn more, visit http://www.ieee.org/societies_communities/geo_activities/sections_congress/2017.

—Monica Rozenfeld

CORRECTION

"Nominations Needed for Technical Field Awards" [June, p. 19] omitted Wolong Electric Group Co. Ltd., a cosponsor of the IEEE Nikola Tesla Award.

Calendar of Events

SEPTEMBER

12-15

IEEE International Smart Cities Conference in Trento, Italy.



17

IEEE N3XT Global Entrepreneurship Summit in Austin, Texas.



24-25

Region 8 meeting in Porto, Portugal.

OCTOBER

3

Last day that marked annual election ballots can be accepted by IEEE.

14-15

Region 7 meeting in Ottawa.

17-19

IEEE International Conference on Rebooting Computing in San Diego.

20-21

IEEE Technology Time Machine in San Diego.



28

IEEE-Eta Kappa Nu Founders Day.

NOVEMBER

16-21

IEEE Meeting Series in New Brunswick, N.J.

20-21

Election results are made official by the IEEE Board of Directors.



This photo of the IEEE student branch at the University of Los Andes, in Bogotá, won first prize in the 2015 IEEE Day photo contest.

SPECIAL REPORT

ENGINEERING EDUCATION



TODAY'S HIGH-TECH

companies can't find enough skilled engineering grads and workers, while universities and employers are struggling to keep up with advances in technology. Education is key, but what is the current state of engineering education in schools and in the workplace?

In this special report, *The Institute* asked leaders of engineering schools

around the world about the issues they face in getting young people prepared to enter the workforce [article, right].

Augmented reality, virtual reality, and 3-D printing are being used as teaching and study aids [p. 8].

On-the-job training has become an essential tool for businesses to maintain a competitive edge. Verizon and VMware, for example, are offering training tailored to employees' needs, in a variety of formats [p. 10].

Included in this report are expert tips and resources to help you break into some of the fastest-growing technology fields [p. 11]. And you'll find IEEE educational products and services [p. 16] to take you through each stage of your career, as well as conferences that tackle issues of concern to educators [p. 17].

The report also offers a profile of the person who helped bring MOOCs to the world: IEEE Senior Member Anant Agarwal, CEO of edX [p. 18]. We also feature IEEE Fellow Richard Baraniuk, who created a platform on which to customize course materials—and he offers them for free [p. 19].

It's not just people who need to adapt and evolve, but organizations, too. IEEE President Barry Shoop describes steps IEEE has taken to stay relevant [p. 13].

Visit theinstitute.ieee.org for blogs related to this special report. To tell us what you think of today's engineering education landscape or to comment on what you read in this report, email the editors: institute@ieee.org.

—Kathy Pretz, editor in chief

The State of Engineering Education Worldwide

Top IEEE educators share their views

BY KATHY PRETZ

THE NEED FOR qualified engineers has never been greater. Engineering schools are increasingly under pressure to build young people's job readiness as the labor market demands better-skilled workers.

There are other challenges as well. At some schools, the student body is older and more culturally, ethnically, and economically diverse. Others find that enrollment in science, technology, engineering, and math (STEM) disciplines at the high school level is decreasing, so fewer students are applying. The amount of material that's required to be covered continues to increase.

These are just some of the issues that leaders of engineering schools shared with *The Institute*, along with what they're doing to address them.

DIVERSITY

Nearly all the educators noted that diversity is a concern as well as an opportunity. But the term *diversity* can mean something different to each one.

A student body composed of more adults and people with different ethnicities and cultures is what it means for IEEE Fellow S.K. Ramesh, dean of the College of Engineering and Computer Science at California State University, Northridge. He's also vice president of IEEE Educational Activities.

"Twenty-some years ago, we did not have the sort of diversity in the student body that we're seeing today," Ramesh says. "We are seeing many more first-generation students and nontraditional students who are balancing life and work responsibilities as they pursue their degrees.

"One thing we must do to attract traditionally underserved populations is to look at the way we're teaching our courses to see whether they're culturally sensitive and they're relevant to students from diverse backgrounds and cultures."

For instance, one of the programs he's involved with, TIDES (Teaching to Increase Diversity and Equity in STEM), incorporates



culturally relevant music references into core introductory programming courses, improving student retention and success. The TIDES modules are available at no charge to anyone around the world.

“We need to address the challenges of an increasingly diverse student body by ensuring that faculty are aware of the different cultural backgrounds and life experiences of their students and are inclusive and empathetic to diverse learning styles,” he says. “What works in North America may not

work in Southeast Asia or Latin America.” By adopting culturally sensitive teaching methods, he adds, faculty can help engineering become more relevant and meaningful for students from different cultures and backgrounds.

To 2006 IEEE President and Fellow Leah Jamieson, dean of engineering at Purdue University, in West Lafayette, Ind., diversity means including more women in engineering programs. About 19 percent of students in U.S. engineer-

ing programs are women, Jamieson says, but she proudly points out that for the 2015 fall semester, women made up 29 percent of Purdue’s first-year engineering class and about one-quarter of all its engineering students.

“We’re thrilled that we’re above the national average,” she says, “but that’s because we work at it like crazy.”

“A wealth of research shows that innovation and diversity are intimately connected. If you have people with different backgrounds,

different perspectives, different life experiences, and different ways of thinking about a solution to a difficult problem, the diverse team is going to come up with more creative solutions.”

In South Africa, IEEE Senior Member Saurabh Sinha serves students from diverse socioeconomic backgrounds and with varying degrees of educational preparedness. Sinha is the executive dean of the faculty of engineering and the built environment at the Univer-

sity of Johannesburg. He is also a past vice president of IEEE Educational Activities.

“South Africa’s higher education institutions inherited generational challenges brought about by apartheid and have to cope with a ‘two-tiered’ national economy: one that is first-world and the other in the emerging world,” he says.

we’ve had rather disappointing enrollment numbers in electrical engineering in the last three or four years,” Tsang says. He also attributes the drop to misconceptions about employment opportunities and salaries for engineers.

“The impression is there are really no high-tech employers in Hong Kong and, therefore, a

well as classes in time management, confidence building, and advanced study skills. “With this assistance, the aim is to reduce student drop-out rates,” Sinha says.

Ramesh reports that California ranks last out of the 10 U.S. states with the largest Latino student populations for the percentage of Latinos earning bachelor’s degrees in engineering and computer science. That’s according to the Campaign for College Opportunity, a nonprofit advocacy group focused on higher education. Excelencia in Education, a not-for-profit advocacy group that hopes to accelerate Latino student success in higher education, has partnered with the Campaign for College Opportunity to help California’s Latino students. The state has a 10 percent gap between Latinos and whites when it comes to graduation rates, the group says.

“Clearly we have a big gap in achievement,” Ramesh says, “and we are working to turn things around with cohort-based programs to improve student support, mentoring, and tutoring.”

One way to keep students engaged and continuing their engineering studies, Ramesh and Sinha agree, is to involve them in hands-on projects, like those found in EPICS (Engineering Projects in Community Service) in IEEE. Rather than working only on problems posed in the classroom, high school students involved with EPICS are matched with IEEE volunteers and student members to collaborate with community organizations on engineering-related projects. Jamieson started EPICS with Purdue colleagues in 1995 as a way to address feedback from industry at the time that engineering programs were not equipping students with essential professional skills.

“These types of community service programs inspire the next generation of students and help them understand why engineering is so important,” Ramesh says. “At the end of the day, how are engineers using their knowledge and their technical backgrounds to help the community at large?”

CAN’T TEACH IT ALL

The educators agree that the traditional four-year bachelor’s degree program does not provide enough time to cover the fundamentals and provide training in specialized areas.

The first semester is spent teaching fundamentals and, in Hong Kong, Tsang notes, covering basic science and math concepts that used to be taught in high school. “We’re finding it extremely tough to teach everything we think we should within the usual four years,” he says.

Schools are under pressure from industry, Jamieson says, to teach nontechnical skills such as teamwork, verbal and written communication, ethics, and how to combine technical and business perspectives. “No one wants to take away any of the technical skills or stop teaching foundational math and science courses,” she says, “but the broad set of skills expected of the graduate continues to increase.

“We need to recognize that when students graduate they’re not going to know everything, and the education they get at a university must be a really effective springboard to learning throughout their careers.”

Schools should stick to teaching the fundamentals, Ramesh says, because there are many subjects that universities can’t possibly teach given their time constraints and resources.

“Students need academic rigor,” he says. “Ultimately, when students go into industry or graduate school, they’re going to be using the fundamental skills learned as an undergrad.” It’s up to individuals to take ownership of their careers and stay technically current, he adds.

Sinha notes that the University of Johannesburg is experimenting with new methods focused on the learners, not just the teachers. That includes student-centered education, whereby the student takes the lead in explaining a topic and the lecturer is the facilitator. There’s also so-called active learning or learning by doing.

“This approach takes the learning of fundamentals and applies it to practical problems,” Sinha says. “It links advanced mathematics to the reality of engineering to get learners excited about the importance of STEM.”

Engineering schools need a more systematic, rigorous, and scholarly way of continuing to improve, Jamieson says, because “there are always going to be challenges, and the pace of change is always going to be fast.” ♦

Start talking about the fact that engineers make a difference in the world

Because of historical segregation, he says, “universities receive students with exceptional potential—bearing in mind that very few have access to universities—but with wide-ranging levels of preparedness in STEM subjects.” His university has addressed this by developing varied first-year programs, including extended programs.

“Among others, we offer students who can’t cope with these educational differences a bridge year,” he says. They take additional courses in math and science and are gradually given a heavier workload than they might be used to, thus preparing them for what they’ll find in the university. “The first-year experience is essential for their preparation,” he says.

DECLINING ENROLLMENT

Universities in Hong Kong are having a difficult time attracting students to engineering, especially electronics engineering, according to IEEE Senior Member Hon Tsang, who chairs the department of electronics engineering at the Chinese University of Hong Kong. He’s also a member of *The Institute’s* editorial advisory board.

“Since about 2012 we’ve seen a sharp decline among high school students who study calculus and physics,” Tsang says. That’s when the country’s high school system went from one based on a British model (which required seven years of study) to one modeled after mainland China’s (six years).

“Because engineering relies heavily on math and science,

lack of job opportunities,” he says. But engineers are needed, he notes, in banking, logistics, insurance, and other service industries. Because demand outstrips supply, Tsang says, all his school’s engineering graduates are employed within a year.

“That’s good news for our graduates,” he says, “but bad news for industry, because we’re not supplying the number of engineers they need.”

Entry-level salaries for engineers are lower than those for doctors and lawyers, he concedes, but after two or three years, engineers’ salaries increase rapidly.

Hong Kong’s educators and industries have begun to work on ways to address the drop in enrollment, he says. One suggestion is to improve the public’s awareness of the importance of science and engineering and the career opportunities that exist.

Jamieson agrees that the right message is important. She points to the *Changing the Conversation* report published in 2008 by the U.S. National Academy of Engineering.

“I felt it was trying to shake us by saying, ‘Stop talking about the skills you need and about how you have to love math and science and start talking about the fact that engineers make a difference in the world,’” she says. “The academy did a really nice study of public perceptions, and we [at Purdue] took it to heart. We changed how we talk to prospective students.”

In South Africa, a student’s first-year university experience involves tutors and mentors as

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Wiring Students to Succeed

Tech tools are being used as teaching and study aids

BY MONICA ROZENFELD

TECHNOLOGY will undoubtedly play an important role in educating the next generation of students. After all, many of today's gadgets are already second nature to kids. Here are several technologies being used now in preuniversity and college classrooms.

AUGMENTING EDUCATION

Augmented reality and its applications for learning provide an interactive experience for students. Take the Microsoft HoloLens, for example. The headset [see photo, bottom right] blends the digital realm with the real world by superimposing 3-D images, from holograms, in front of the user.

A camera in the headset tracks the position of the wearer's hand, letting the person manipulate holographic images placed in front of her. A student looking at a 3-D hologram of the solar system in class, for example, could reorder the planets by "grasping" their images and moving them.

Some classrooms are starting to test the HoloLens, which went on sale in March. Anatomy students at Case Western Reserve University, in Cleveland, are using it to view the human body as a life-size hologram. They can see a body with or without muscles, and they can zoom in on parts they're studying, like blood vessels, ligaments, organs, or the nervous system. The AR tool can help students simulate medical procedures, too, such as identifying and removing a tumor.

Budding mechanics enrolled in the automotive repair program at Clackamas Community College, in Oregon City, Ore., are applying the HoloLens starting this month. The device can superimpose holographic images onto car parts so that students can learn to identify and repair them. The auto repair program partnered with Intel and Oregon Story Board—a Portland nonprofit specializing in digital tools for storytelling—to help align the AR application with the college's curriculum.

FULLY IMMERSED

The Google Cardboard platform [see photo, left] is bringing the full immersion of virtual reality to the classroom. You fold a cardboard viewer into gog-

CLOCKWISE FROM LEFT: GOOGLE; MAKERBOT; CASE WESTERN RESERVE UNIVERSITY

gles so that it suspends a smartphone about 5 centimeters in front of your eyes. Plastic lenses on the viewer bend light to create 3-D images from what is displayed on the phone's screen.

The Google headsets can display a host of mobile VR apps and provide a virtual experience of places being studied in the classroom. Discovery VR, for example, can supply 360-degree views of the Grand Canyon or a view of Earth from a suborbital spacecraft.

The InMind VR app takes students inside a generic human brain to better understand neural anatomy. Students can use the app to hunt down neurons that cause psychological disorders.

At last year's International Society for Technology in Education conference, keynote speaker Soledad O'Brien said Google Cardboard and other VR tools can expand students' horizons by immersing them in environments that simulate different careers. They can see what it would be like to be, say, a firefighter or police officer, or a veterinarian. O'Brien is a broadcast journalist who

founded the Starfish Foundation, which helps underprivileged students get to college and graduate through financial assistance and mentoring.

Unimersiv, which offers a platform for VR educational experiences, says students are more likely to remember information by experiencing it than by reading about it. The platform can help students of all ages learn through VR, according to the company's website.

But VR technology does have drawbacks. The constant motion on the screen can cause motion sickness. And the experience might make some students feel vulnerable, as if they've been removed from their surroundings.



MakerBot, a manufacturer of 3-D printers like the Replicator desktop printer (left), has partnered with universities to set up Innovation Centers to teach students digital design and 3-D printing skills.

MAKE IT YOURSELF

One of the fastest-growing technological trends in preuniversity education is 3-D printing, according to the New Media Consortium's 2015 *Horizon Report: K-12 Edition*.

In an interview with *EdTech: Focus on Higher Education*, Jordan Brehove, MakerBot's vice president of solutions, says the power of 3-D printing in education isn't merely replicating existing ideas but giving students the ability to imagine new products and designs and then to build them. A manufacturer of 3-D printers, the company is partnering with universities to set up MakerBot

Innovation Centers. Hong Kong Polytechnic University opened the first such center in May to teach digital design and 3-D printing skills.

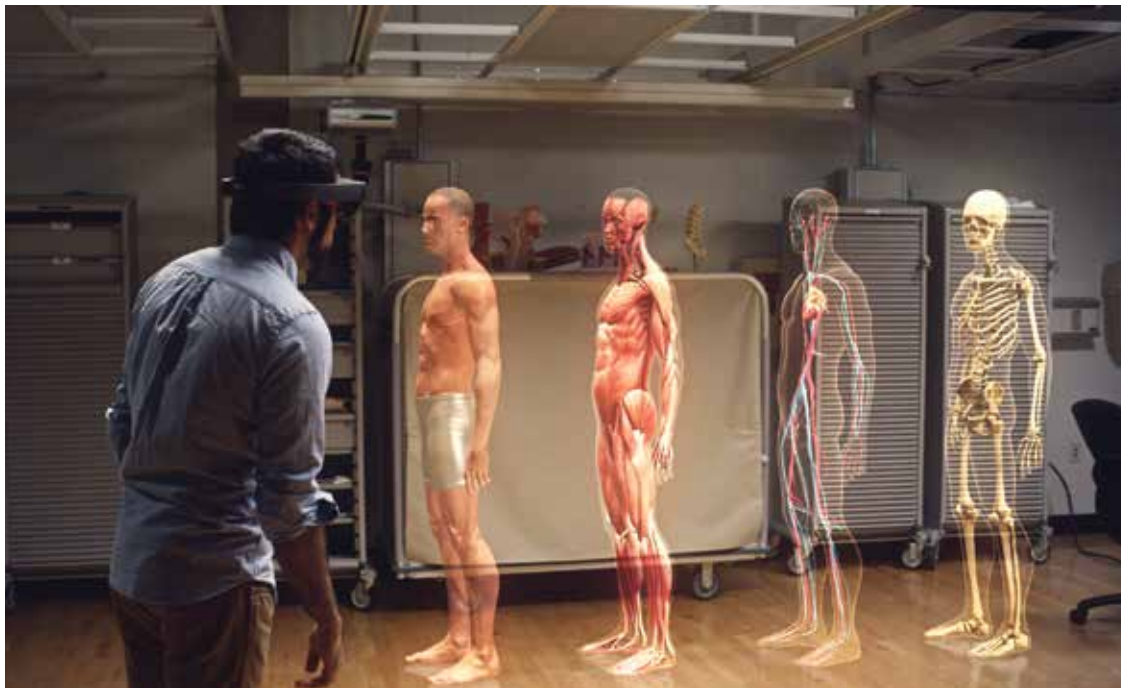
Starbase, a nonprofit program in Minnesota, aims to get inner-city students interested in the sciences with an aerospace-themed curriculum in which students plan an imaginary mission to Mars. Students use 3-D printers to design and print a working rocket made from plastic that they launch on the program's final day.

In Australia, students at Darwin High School who create products with 3-D printers practice entrepreneurial concepts involving design, prototyping, and marketing.

USES FOR WEARABLES

Students can use wearable devices for more than counting steps or tracking sleep patterns. The brain-sensing headband Muse can help students understand how the brain reacts to various stimuli—which can lead to interesting experiments in the classroom. Data collected from the headband about the wearer's brain activity, displayed on a smartphone or tablet, can help students determine when they're most focused and where they should do their studying.

Several organizations are teaching students to create their own wearables. The IEEE Women in Engineering group has held workshops for students on how to design and sew wearables into garments. And companies including AdaFruit Industries and JewelBots teach students how to program jewelry to alert them when important text messages are received, say, or when friends are nearby. ♦



Anatomy students at Case Western Reserve University, in Cleveland, are using the Microsoft HoloLens, an augmented reality headset, to view the human body as a life-size hologram. The headset superimposes 3-D images in front of the user.



Innovative Ways Keep Employees' Skills Updated

Corporate training programs are being customized to workers' needs BY KATHY PRETZ

ADVANCES IN technology and a competitive business environment mean today's companies often need to upgrade their employees' skills. On-the-job training has become an essential tool for engaging employees, attracting and retaining top talent, and developing leaders, according to the annual *Deloitte Global Human Capital Trends* report.

Almost 85 percent of the 7,000-plus human resources and business leaders who responded to this year's Deloitte survey rated learning as important or very important.

To find out how some large high-tech companies are addressing their employees' professional development needs, *The Institute* interviewed representatives from Verizon and VMware, which have sponsored IEEE events.

We also spoke to a former chair of the IEEE Educational Activities' Continuing Education Committee about the organization's efforts to help members with training.

A COMPETITIVE EDGE

Well-trained employees are critical to Verizon's success, says Marianne Groth, senior manager of technical training with the company's Learning and Development group. Verizon is one of the largest communications technology companies.

"If we don't provide the training, our folks just aren't going to have the skills we need," she says. "We see technology as very much the enabler to drive the business.

"You have to give employees all sorts of opportunities, because things move so fast in this world that

sometimes formal training courses can't catch up to the technology."

Historically, the company's technical training was focused on employees in IT and data-center and user-support services, but these days "everyone in the company needs to understand technology," she says.

"Our scope is still on the very technical folks," she says, "but we offer some level of technical training to everyone, because we know it helps the company stay competitive to have a technology-savvy workforce."

INNOVATIVE PLATFORMS

According to the Deloitte report, today's successful professional development programs help workers figure out how to obtain needed training—and in a format that suits their schedules.

Verizon and VMware, a virtualization software company in Palo Alto, Calif., offer formal and informal training on technical and soft skills. They use a variety of formats including massive open online courses, instructional videos, simulations, and e-books. The training is role based and can be taken on company time.

If Verizon's employees can't find the training they need among the company's offerings, the company gives them access to Skillsoft online courses, videos, and books, and they can purchase individual licenses to Lynda.com. The two online libraries contain thousands of courses.

VMware provides access to Pluralsight, which offers online technical and soft-skill training, as well as Jhana for management skills plus the CEB (Corporate Executive Board) Corporate Leadership Council program.

IEEE members and others should explore the training resources that IEEE offers, says Ken Pigg, past chair of the IEEE Educational Activities' Continuing Education Committee. The resources are geared toward different stages of a career [p. 16].

For more specialized needs, Verizon and VMware develop custom courses using internal experts as well as vendors. At VMware, for example, principal engineers, senior staff engineers, and executives deliver boot camps covering products, solutions, architecture, and strategy. They also deliver workshops on such subjects as creating secure code. VMware's Global People Development team partners with business unit leaders to anticipate emerging technology trends and to develop courses to teach needed skills.

"As a disruptive, innovative company, we are always looking for leading-edge learning opportunities," says Tamara Scholz, senior director for the company's R&D engineering training group.

CAREER DEVELOPMENT

VMware takes training a step further with a three-part program: Take 1 Refresh, Take 2 Reignite, and Take 3 Rejuvenate. "This program reimagines the traditional professional development assistance concept," Scholz says. "It builds on a successful internal sabbatical program we piloted in 2011 in R&D that is now open to all employees to help them figure out what's next for them at VMware."

In Take 1, employees who've been with the company for a year can refresh their skills and mind-sets by attending industry and academic conferences, workshops, and training sessions—all of which may be unrelated to their jobs.

Offered to employees who've been with the company for three years, Take 2 allows them two weeks away from their jobs to broaden their experiences and enhance their careers. They can explore new areas of the organization, spend time with different teams or with customers, or try to solve a particular problem or work on a new process.

Take 3 lets employees with five or more years of service take three months off to work on a project unrelated to their job, either within the company or with a nonprofit partner.

"Unlike traditional sabbaticals, Take 3 helps employees tap into ongoing projects and new initiatives around the company while encouraging them to explore things they may have never imagined," Scholz says. Some of the projects have combined learning objectives with community service.

"All three programs reflect our understanding that the types of people who work here—innovators and entrepreneurs driven to find creative solutions for thorny problems—thrive on being challenged to grow on multiple fronts," she says.

OUTSIDE WORK EXPERIENCE

Both companies support informal training such as participating on boards of other organizations, writing white papers, presenting papers at conferences, getting involved with educational programs for preuniversity students, and volunteering for organizations such as IEEE.

Serving on IEEE committees and holding volunteer positions within the organization are ideal ways for members to pick up new skills, Pigg says.

"IEEE members should take advantage of the investment they make with their dues and take on some volunteer responsibilities," says Pigg, who has been volunteering for 15 years, holding positions in local sections, with regional organizations, and at the board level. ♦



How to Break Into Some of the Fastest-Growing Tech Fields

IEEE resources to help members launch successful careers BY **AMANDA DAVIS**

ARE YOU A RECENT grad wondering how to establish yourself in a burgeoning field, or are you a working engineer looking to take your career in a different direction? IEEE can help. *The Institute* has compiled tips from experts on how to break into some of the fastest-growing technology sectors. IEEE also offers many educational resources.

BIG DATA

Because more devices are being connected to the Internet every day, there's a large demand for those with big-data skills. *Forbes* magazine reported that in 2015 alone, Cisco, IBM, and Oracle together advertised nearly 27,000 job openings that required expertise in this area.

Three important skills are needed, according to Dennis Shasha, associate director of NYU Wireless, a research

institute at New York University. The first is an understanding of databases and how they manage large amounts of data. Next is knowledge about machine learning and data mining, which allow inferences to be made from data. Last is a grasp of statistics, so you can estimate the reliability of your conclusions.

It also helps to have an inquisitive personality—a cross between that of a detective and a journalist. “The more questions you ask,” Shasha says, “the more you'll learn from the data.”

Big data has applications in every field and every industry, says IEEE Fellow Manish Parashar, founding director of the Rutgers Discovery Informatics Institute, in Piscataway, N.J. He notes that people already working in electrical engineering, computer science, or another high-tech field could move their career in that direction by adding data-science skills to their knowledge base.

The IEEE Big Data initiative offers several resources, which are listed on its Web portal (bigdata.ieee.org).

A free online course, Introduction to Data Storage and Management Technologies, covers differ-

ent types of systems and networking techniques as well as concepts related to business continuity, data security, and data management. The course is available on demand at IEEE.org, the IEEE portal of edX, a provider of massive open online courses (MOOCs) [p. 18].

SOFTWARE-DEFINED NETWORKING

Software-defined networks decouple hardware (such as for forwarding IP packets) from software (the control plane that carries signaling traffic for routing through the network devices). SDNs execute such software not necessarily in the equipment but either in the cloud or in clusters of distributed IT servers. These networks are bound to become increasingly popular as more open-source software becomes available and traffic on telecommunications networks skyrockets.

With the softwarization of telecommunications infrastructures, IEEE Member Antonio Manzalini, cochair of the IEEE Software Defined Networks initiative, says engineers will need several skills to develop SDN tools, products, infrastructure, and

applications. Included is an understanding of industrial mathematics, a mastery of software architecture and open-source software, a background in big-data analytics and, last but not least, cybersecurity expertise—“because security must be everywhere within SDNs,” Manzalini says.

The SDN initiative offers educational resources on its Web portal (sdn.ieee.org), including introductory tutorials that focus on the concepts behind SDNs and their roles in the networking market. There's also a two-part course, Introduction to Software-Defined Networking, taught by IEEE Fellow Raj Jain, a professor of computer science and engineering at Washington University in St. Louis.

BIOMEDICAL ENGINEERING

The field of medicine needs people who understand technologies like automation, computing, diagnostics, imaging, and product safety, says IEEE Fellow Donna Hudson, chair of the IEEE Life Sciences Technical Community. In other words, it needs biomedical engineers.

Just about anyone already working in technology could switch over to the life sciences, Hudson says, although it's helpful to have a working knowledge of biology. That can be gained through a few introductory courses on such topics as anatomy, cell biology, and epidemiology.

For some areas—such as medical informatics, which combines medicine and computing—getting a doctorate or master's degree in biology or a related field might be necessary. For those unsure of which area of the life sciences to pursue, it is helpful to talk with those working in different aspects of medicine.

There are also MOOCs available on IEEE.org. On-demand courses include So You Want to Become a Biomedical Engineer, a free four-week class that provides an overview of the key areas of biomedical engineering, as well as its recent advances. The course also provides tips on how to navigate a successful career in the field.

Those ready to take the plunge into biomedical engineering can sign up for the IEEE Engineering in Medicine and Biology Society's annual summer schools. Each summer program typically lasts for 7 to 10 days, bringing together students and professionals in industry and academia. Scholarships are available for students with need who wish to attend. You can find out more about upcoming programs at <http://www.embs.org/conferences-meetings/summer-schools>. ♦

“Free” Articles Are Anything but Free

There’s a price for accessing illegally downloaded material BY KATHY PRETZ

NONE OF US wants to pay for things if we can get them for free. But what if an item were stolen? Would you still take it? Most people would say no, unless they’re Sci-Hub users. Researchers and students around the world are using the pirated-content website to download for free any of more than 50 million research articles, monographs, and book chapters that Sci-Hub obtained illegally. The material originated at science, technology, and medical (STM) publishers—including not-for-profit ones.

Articles from IEEE are on the website, as well as ones from the American Association for the Advancement of Science, the American Chemical Society, Elsevier, the Institute of Physics, Oxford University Press, and the Royal Society of Chemistry. IEEE’s content is the third most downloaded, according to an analysis by *Science* magazine.

Elsevier has filed a lawsuit in U.S. federal court in New York.

“The intellectual property has been stolen from not just commercial publishers but also from not-for-profit publishers like IEEE as well as university presses,” says Fran Zappulla, senior director of IEEE Publishing Operations.

PIRATED MATERIAL

Alexandra Elbakyan, a researcher from Kazakhstan, launched Sci-Hub in 2011 for what she likely believes were good intentions. She wanted everyone, especially researchers in developing countries, to “freely share in scientific advancement,” she said. The problem is Sci-Hub contains copyrighted material that has been illegally obtained.

“Sci-Hub would not exist were it not for the work of IEEE and other publishers,” says Renny Guida, IEEE’s director of product management, whose area oversees the IEEE Xplore Digital Library.

According to news reports, Sci-Hub discovered vulnerabilities related to

institutional subscriptions to STM publishers’ digital libraries, which are the primary source for content. And some people who support Elbakyan’s cause willingly gave their sign-on names and passwords.

The analysis by *Science* of Sci-Hub’s 28 million download requests, made over a seven-month period, showed that researchers and students from developed as well as developing countries used the site. Released in April, the study showed that between September 2015 and March 2016, people in China, India, and Iran downloaded the most articles, but even users in areas where legitimate, paid access is likely available were frequent visitors. In the United States, the most downloads came from California, New York, and Virginia.

“People who are accessing articles through Sci-Hub are free riding on the backs of legitimate users, who pay the costs,” Guida says. “But nothing comes for free. Maintaining a quality publishing program and hosting that content on a robust and reliable platform is only sustainable when libraries, organizations, and individual researchers pay to subscribe to it.”

FREE, AT A COST

Modern publishing services—including the infrastructure that supports the thousands of volunteers in the peer-review and editorial processes, as well as convenient online delivery—are expensive.

Costs can include those associated with building and maintaining a Web-based system that lets authors submit their papers at any time, Zappulla notes. There are also content management systems that keep track of articles as they’re submitted, peer-reviewed, and revised to provide critical feedback to authors and further the scholarly publishing process. Copy editing, text formatting, and graphics processing take place before a manuscript is finally published and uploaded to a digital library.



“Whether they are on the Web or in print, authors still want their articles to be easily discovered and read and to look good,” Zappulla says. “None of that is without cost.”

And for IEEE there’s the cost of keeping its platform, the IEEE Xplore Digital Library, running at the state of the art.

Added to those investments is the cost of archiving the material to “ensure the content will be available for posterity, no matter what happens,” Guida says. “The costs of continuing to create and develop the outstanding scholarly journals that IEEE and other STM publishers have introduced over the years must be covered.” Revenue from traditional subscriptions pays for those services, Zappulla says.

OPEN ACCESS

IEEE and most scientific publishers have several pricing levels and multiple options available so that researchers who don’t have much money may access documents. Also, most scientific and technical publishers offer special pricing to academic consortia. For example, schools that don’t have graduate programs but need at least some content pay a significantly discounted price, Guida says.

IEEE also notes an important part of its mission is to make its scholarly articles widely available. Accordingly, it offers some for free. With such open-access articles, the authors—or their funding organizations—pay the processing fees. In addition, IEEE allows authors to post the

accepted versions of their manuscripts on their own websites and on their institutions' or employers' websites.

"IEEE has also broadened its offerings to include publications that only publish open-access articles," Zappulla says. "Today, almost all our journals have a mix of traditional subscription-funded articles and ones that are open access."

There's also *IEEE Access*, an open-access multidisciplinary journal that publishes articles across all of IEEE's fields of interest.

WHAT'S THE HARM?

Elbakyan and the people who maintain Sci-Hub apparently believe they are performing a service to researchers in developing areas. But they are likely to create a domino effect in which organizations wishing to help those researchers will not have the financial resources to do so.

For example, funds IEEE receives from the sale of its content are reinvested in humanitarian-related technology activities. These include community service projects that, for example, bring power and communications to underdeveloped areas, outreach activities to encourage interest in the engineering profession, career development resources for engineers, and confer-

ences in remote regions of the world to enable engineers to share their ideas, collaborate, and introduce breakthrough technologies.

Further, the content on Sci-Hub is not regularly updated the way the material on the publishers' digital libraries is. Those who download an IEEE standard from Sci-Hub, for example, could be accessing a version that is out of date—which could lead to glitches, major failures, and even safety concerns.

So if you happen to see colleagues or classmates about to download material from Sci-Hub, remind them how much those free articles might actually cost others. ♦

IEEE as a Learning, Adapting, and Evolving Organization

We must embrace change or accept irrelevance

BARRY L. SHOOP IEEE PRESIDENT AND CEO



IN THE SIXTH century B.C.E., the Greek philosopher Heraclitus of Ephesus wrote, "Everything changes, and

nothing remains still.... You cannot step twice into the same stream." Change is an ever-present constant in our personal and professional lives. As technical professionals, we need to maintain currency in our disciplines and professions to remain relevant and competitive in an increasingly dynamic and ever-changing environment.

It is equally important for organizations to adapt and evolve with changing conditions. Our world is becoming more complex, more competitive, and flatter as the speed of technological advancement increases.

As just one example, global Internet traffic in 1992 was roughly 100 gigabytes per day. By 1997, it had increased to 100 GB per hour, and in 2002, the traffic reached 100 GB per second. By 2015, traffic had grown to nearly 20,000 GBps. And the trend continues.

According to Gartner, a leading information technology research and advisory company, the Internet of Things will connect some 21 billion devices by 2020. In addition, the volume of digital data we produce every year will increase tenfold to 44 trillion GB. At the same time, we are putting to use more of the growing volume of data. In 2013, only about 5 percent of the data generated was tagged and analyzed; by 2020, we could be using 35 percent of a much larger data stream, according to the 2014 *EMC-IDC Digital Universe* report.

As a large and complex organization supporting the technical and professional needs of our members, our professions, and the public, IEEE recognizes both the acceleration of technological innovation and the challenges this brings. After all, IEEE's membership drives much of today's exponential rate of technological growth.

A NEED TO EVOLVE

The imperative is that IEEE understand this changing environment and evolve to position itself for the future. As GE's CEO, Jack Welch, famously wrote: "We've long believed that when the rate of change inside an institution becomes slower than the rate of change outside, the end is in sight."

To be sure, in the last several years, IEEE has made remarkable progress in accelerating its internal rate of change. Our recent senior leadership should be congratulated for taking bold steps to improve the organization's global positioning.

In April, for example, IEEE acquired GlobalSpec and its Engineering360 information and collaboration platform [see p. 3].

In May, IEEE launched the International Roadmap for Devices and Systems, an extension of the International Technology Roadmap for Semiconductors that will build a comprehensive end-to-end view of the computing ecosystem, including devices, components, systems, architecture, and software.

Earlier, we launched the IEEE Internet Initiative, which has helped place IEEE among the leading trusted authorities in the ongoing evolution of the Internet.

We also created IEEE Collaboratec, which now facilitates a collaborative community numbering in the tens of thousands. And through a partnership with IP.com, IEEE established InnovationQ Plus, building a powerful platform that combines IEEE content with IP.com's global patent and non-patent literature to aid innovators around the world. In addition, we set up the Humanitarian Activities and Global Public Policy committees and expanded our global activities in Asia and Europe.

CHANGE AGENTS

To continue this momentum, IEEE needs proactive innovators and change agents throughout our entire organization. We must constantly rethink and improve how

we do almost everything: how our societies, sections, chapters, and interest groups operate; how we communicate and collaborate across organizational and geographic boundaries; and how we make decisions.

While this sounds logical and straightforward, it is not easy. Change is hard. It comes with uncertainty, risk, and fear. Those who push boundaries often encounter resistance. Those who innovate sometimes fail. Even technology giants like Edison, Shockley, and Turing didn't make their breakthroughs on their first attempts.

Ultimately, each of us can be change agents of one kind or another. Some prefer to lead change. Others prefer to be open to new thoughts, ideas, and approaches and to enable change by sharing their insights and perspectives. We all can drive change through our willingness to contribute to the process of change. To succeed in any attempt to change, we must be willing to fail; but, more importantly, we must be willing to rise again, learn from our experiences, and improve. As a living, learning organization, this should be ingrained in IEEE's culture as part of our organizational DNA.

Make no mistake: When it comes to change, the stakes are high. The long-term survival of IEEE as a professional society is at stake.

In early 2000, while he strove to transform the U.S. Army, one of the world's largest organizations, its chief of staff, Gen. Eric Shinseki, said, "If you don't like change, you're going to like irrelevance even less." That is our challenge: Embrace change or accept irrelevance.

As our members drive ever-faster technological change, each of us must play a role in guaranteeing that our professional society remains relevant, that it is as innovative and agile as our members are, and that it continues to evolve to meet the challenges of the increasingly dynamic world around us. Contact me: president@ieee.org. ♦



Sparking Conversation on Artificial Intelligence

In June, The Institute focused on AI, including deep learning, in which neural networks teach themselves and make decisions on their own. The issue also featured noteworthy AI applications and gave tips on how to break into the field, along with what jobs are likely to be available for humans as more tasks become automated. The conversation continued on our website: <http://theinstitute.ieee.org/artificial-intelligence>.

DEEP LEARNING

Long ago, when working on my Ph.D., I had some involvement in AI. At that time, we focused on pattern recognition and adaptive systems. I don't see that a lot has changed since, except that adaptive algorithms have become far more sophisticated.

At one time, researchers thought that computer code could become smart enough to modify itself for the better. Not long afterwards, hard walls in virtually all processors were placed between code and data to absolutely prevent any code modifications, as they invariably led to chaos. Self-modifying code never became smarter. It always became dumber.

Machines beating humans at chess and Go are just using better algorithms, not intelligence. Maybe some day machines can achieve real intelligence, but I think that "singularity" is still a long way off.

—*gordonapple*

EVERYDAY AI

I'm just as excited about AI as anyone else, but I really do implore everyone—including those who fear it—to understand what AI truly is. With no standard, things are being labeled AI when they shouldn't be. Filling in the blanks of a news article, for example, is not artificial intelligence; it's an automation process. But because there are no set standards within this field, companies are pretty much free to exploit the concept and call anything AI.

We need to step back and make clear and responsible distinctions. Otherwise, we'll just create a bubble of fear within the very market that might benefit from it. And that's not very intelligent at all.

—*Nicole Miller*

NOT SO IN DEMAND

I have a Ph.D. with a concentration in AI and 14 years of experience in industry and government with AI and machine-learning applications. I get about one response for every 50 résumés I send out and maybe one interview per year. If your résumé doesn't list the specific combination of software platforms and tools the potential



employer plans to use and you didn't go to Carnegie Mellon, Stanford, or MIT, no one wants you for AI or machine-learning positions.

—*Bad Horse*

ROBOTS FOR HIRE

As more jobs are automated, people incapable of learning tech-related skills will be given a monetary allowance and food by the state, paid for by increased taxes. Work will no longer be promoted as necessary to a good or worthwhile life.

—*ProfStewart*

Robots are not going to take over all professions—they will only reduce jobs that require physical labor. But new technologies will bring new opportunities. Machines will work with humans, freeing them for higher-level tasks.

—*Qusi Alqarqaz*

ROBOT CONTROVERSY

When robotics company Boston Dynamics wanted to show off how its doglike robot Spot could keep its balance, it filmed its employees kicking it. We asked readers whether it was ethical to kick a robot.

I'm sure the people claiming this is unethical have never built a com-

plex robot or worked on one in any great detail. Dealing with code, mechanical failures, and modularity quickly teaches you that despite their lifelike appearance, these objects are machines and don't feel anything.

You might as well call dismantling a man made of Lego blocks unethical. The Boston Dynamics people were not showing signs of abuse—they were engineers testing a machine by delivering an unpredictable and significant disturbance to a complex control system.

—*Ad Spiers*

Believing it is unethical to kick the robot only if it could feel pain is ridiculous. What makes people feel uncomfortable is seeing the act of violence displayed by a human being against a thing that seems to respond to it. They identify with the robot being kicked, and they don't like that feeling. It's like wincing when you see a person take a baseball bat to a car's windshield.

—*Peter Fera*

Ask the Experts

This is a selection of questions readers submitted to IEEE Fellow Li Deng, chief AI scientist at the Microsoft Applications and Services Group; IEEE Fellow Fatih Porikli, the computer vision group leader at NICTA, Australia's information and communications technology research center; and IEEE Member John C. Havens, executive director of the IEEE Global Initiative for Ethical Considerations in the Design of Autonomous Systems, led by the IEEE Standards Association.

Q: What tasks is AI not good at solving?

Deng: Those requiring creativity, intuition, and common sense. For example, the creation of scientific theory, such as relativity and quantum mechanics, requires huge amounts of creativity and ingenious experimentation. AI will not be able to do that for a long time.

the institute

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ERIC FROMMELT (2)

Q: *If we develop an AI system whose behavior is indistinguishable from that of a human, what rights, if any, should we grant it?*

Porikli: None. Why should there be such rights? We should distinguish fact from fantasy. We are not talking about the *I, Robot* movie, in which humanoids have actual emotions. We are dealing with software running on silicon processors. Rights are contained in the realm of moral consideration and granted to those endowed with perception, emotion, and real intelligence. An AI system, however complex, is still a device—just like a thermostat

responding to sensors or a character in the *SimCity* game responding to mouse clicks.

Q: *Science fiction writer Isaac Asimov postulated rules for smart robots to follow that would keep them from turning on humans. Is it possible for AI machines to follow such rules, specifically when in a self-preservation mode?*

Havens: Asimov's laws provide a great thought experiment regarding the ethics surrounding the control of AI or autonomous devices. But the conundrums he describes in the short story

"Runaround" demonstrate why a simple list of rules alone cannot be universally applied to every situation an AI system encounters.

The need for a larger framework is the inspiration behind the IEEE Global Initiative for Ethical Considerations in the Design of Autonomous Systems. We've created a charter code of conduct that will be available this month. The code is focused on helping technologists deal with tough ethical concerns regarding the implementation of AI and autonomous technologies. Scenarios of robots operating for their own purposes would be the result of poor design rather than malevolence. ♦

LETTER TO THE EDITOR

Restore IEEE's Ability to Provide Ethics Advice and Support

I am writing to urge the IEEE Society on the Social Implications of Technology (SSIT) and the IEEE Technical Activities Board to jointly take the initiative and propose revising IEEE's governing documents to restore the IEEE Ethics and Member Conduct Committee's ability to provide "ethics advice and ethical support" to IEEE members. Having stated that, the questions of "Why change?" and "Which documents should be changed?" need to be addressed.

During the mid-1970s, when IEEE was wrestling with how to enforce the revisions made in 1974 to its Code of Ethics, two positions were debated. Some members of the IEEE Board of Directors only wanted a mechanism for disciplining IEEE members who violated the code. Members of the IEEE U.S. Activities Committee (USAC) and the IEEE Committee on Social Implications of Technology (now SSIT) believed that, in addition to disciplinary action, ethical support needed to be provided to those whose employment was placed in jeopardy for trying to uphold ethical practices.

After all, even to this day Article 10 of IEEE's Code of Ethics states that members (including members of the IEEE Board of Directors) must agree to support other members in upholding ethical conduct as one condition of renewing IEEE membership.

These two viewpoints were subsequently combined and codified in IEEE's governing documents when the Member Conduct Committee (MCC) was created in February 1978. I, along with Life Fellow Stephen H. Unger and others, supported both viewpoints and developed the USAC proposal leading to creating the MCC.

For the next 20 years, disciplinary actions, as well as ethics advice and support, were carried out by the MCC and a companion Ethics Committee, until 1998. I served on both at the time. Then the IEEE Executive Committee and the Board of Directors systematically killed all ethics advice and ethical support services—in effect achieving what board members of the mid-1970s really preferred as the MCC's role: only disciplining members who violated the code.

By 2005, IEEE's governance documents had been revised to codify these restrictions on the Ethics and Member Conduct Committee. Today, the committee can only recommend discipline. You can read the IEEE Ethics History Repository for a historical account: [http://ethw.org/IEEE_Ethics_History_Repository_\(IEHR\)](http://ethw.org/IEEE_Ethics_History_Repository_(IEHR)).

If members trust that the IEEE Board of Directors will do the right thing by upholding Article 10 to support other members, then revising the IEEE governing documents would be sufficient.

However, I believe IEEE members need to take the extra step and exercise their right to propose an amendment to IEEE's constitution in order to formally codify the necessary changes. Once codified in the constitution, no future IEEE board will have the authority to change it on its own without a formal vote by the IEEE membership.

—Walter L. Elden, P.E.
(Retired)
Life Senior Member
w.elden@ieee.org

IEEE IN 2030 CHALLENGE



SEED GRANT SEEKS NEXT BIG IDEA

IEEE is looking for ways to deliver value to engineers and technology professionals working in industry. That's why we created the IEEE in 2030 Challenge.

We're looking to fund short term projects—12 month or less and up to \$40,000— to support innovative, creative, and potentially disruptive ideas to better serve the needs of professionals working in industry.

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PREUNIVERSITY

For young people and educators, TryComputing.org, TryEngineering.org, and TryNano.org are the go-to portals for lesson plans, games, career information, and a list of universities offering programs in computing, engineering, and more focused topics like nanotechnology.

IEEE Spark is a quarterly e-magazine about engineering subjects of interest to teens aged 14 to 18. Each issue focuses on a specific topic, such as 3-D printing, animation, or cybersecurity.

Engineering Projects in Community Service (EPICS) in IEEE provides funds to IEEE volunteers and student members to work with high school students on engineering-related projects in collaboration with community-based organizations. It's a signature program of the IEEE Foundation. To qualify, an engineering project must offer an immediate and broad impact and be sustainable over the long term.

The IEEE Teacher In-Service Program shows IEEE volunteers around the world how to demonstrate to preuniversity educators the application of engineering concepts

to the teaching of science, technology, engineering, and math (STEM) subjects in their classrooms.

UNIVERSITY EDUCATION

The IEEE accreditation portal offers a searchable database of accredited, degree-granting engineering, technology, and computer science programs. In addition to providing information on recognized accrediting bodies and accredited institutions, the site is a resource for those interested in learning more about accreditation methods, objectives, and challenges.

The Virtual Workshop Series on Early Career Faculty Development presents live, Web-based, IEEE-sponsored conferences. Graduate students and those just beginning their careers as instructors can ask faculty members from around the world for advice on, say, how to create a research program, write a grant proposal, or get research published.

IEEE-Eta Kappa Nu (IEEE-HKN), IEEE's honor society, recognizes university students for outstanding academic accomplishments and professionals for their contributions. An invitation to join an IEEE-HKN chapter as an undergraduate is an acknowledgment of academic success, an early indicator of leadership ability, and an opportunity to contribute to both the profession and the community.

IEEE-HKN holds its annual Founders Day celebration on 28 October, publishes *The Bridge* magazine three times a year, and spon-

sors an annual student leadership conference. The Advanced Learning Workshop kit offers resources that enable the honor society's student chapters and IEEE student branches to organize programs on time management, handling stress, effective note taking, dealing with a difficult professor, and similar topics.

The IEEE Standards Education program, a cooperative effort between IEEE Educational Activities and the IEEE Standards Association, promotes the importance of standards in meeting technical, economic, environmental, and societal challenges. It also develops and disseminates learning materials and resources and promotes the integration of technical standards into academic programs of study. IEEE Standards University offers access to courses, videos, workshops, news, and other resources.

FOR PROFESSIONALS

The IEEE eLearning Library, located on IEEE Xplore, contains more than 400 interactive online tutorials and short courses addressing a wide variety of engineering and technology topics. The introductory, intermediate, and advanced-level tutorials are developed and reviewed by leading subject matter experts. Certificates awarding continuing education units and



professional development hours are available upon completion of the courses.

In partnership with edX [p. 18], one of the world's premier nonprofit online learning destinations, founded by Harvard University and MIT, IEEE Educational Activities offers instructor-led and self-paced massive open online courses (MOOCs) via IEEEEx. Most are free of charge. Learners who pass the courses may purchase certificates awarded jointly by IEEE and edX.

IEEE Educational Activities also supports other IEEE groups by offering services such as coordinating and hosting webinars and virtual events and issuing digital certificates and educational credits to their educational event participants.

AWARDS

The IEEE Educational Activities Board Awards recognize and honor individuals, teams, groups, organizations, and companies for contributions to engineering and technical education. Awards are given for meritorious activities and achievements that advance the practice of engineering and of engineering education. There are also scholarships to recognize graduate students for work in electrical engineering, with financial support for their continued studies.

And awards from IEEE-HKN promote and recognize outstanding contributions by students, faculty, and professionals in IEEE's technical fields of interest. ♦

Tracy Parker is the IEEE Educational Activities promotion manager.

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Conferences Cover Tools for Educators

Upcoming events delve into MOOCs, computer-aided learning, and educational games



International Conference on Information Technology-Based Higher Education and Training

ISTANBUL; 8-10 SEPTEMBER

TOPICS: Massive open online courses (MOOCs), multimedia tutorials, distance learning, network-based education and training, interactive learning modules, accreditation, and virtual classrooms.

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Industrial Electronics societies

VISIT: <http://www.ithet.boun.edu.tr>

■ **International Conference on Interactive Collaborative Learning**

BELFAST, NORTHERN IRELAND; 21-23 SEPTEMBER

TOPICS: E-learning, computer-aided learning, virtual educational environments, remote and virtual laboratories, ethics, education with respect to culture and

diversity, the role of public policy in engineering education, and “flipped” classrooms. In a flipped classroom, students watch online lectures, collaborate in online discussions, carry out research at home, and discuss concepts in the classroom with a mentor’s guidance.

SPONSOR: IEEE Education Society

VISIT: <http://www.icl-conference.org/icl2016>

■ **Frontiers in Education**
ERIE, PA.; 12-15 OCTOBER

TOPICS: Education strategies for energy engineering, software engineering, computing and informatics, and engineering design. Sessions are planned on engineering education for preuniversity students and programs that support engineering education research.

SPONSORS: IEEE Computer and IEEE Education societies

VISIT: <http://fie2016.org>

■ **IEEE International Conference on Teaching, Assessment, and Learning for Engineering**

BANGKOK; 7-9 DECEMBER

TOPICS: Accreditation and quality assurance, assessment and evaluation, computational problem-solving, computer-based learning, continuing education, distance learning, educational games, the Internet of Things for education, learning analytics and big data, and marketing and outreach for engineering education programs.

SPONSOR: IEEE Education Society

VISIT: <http://tale-conference.org>

■ **IEEE International Conference on MOOCs, Innovation, and Technology in Education**

MADURAI, INDIA; 9-10 DECEMBER

TOPICS: Evaluation and credit transfer of MOOCs, open-education resources, experimental case studies, use of mobile devices in education, virtual and augmented reality tools for education, and project-based learning.

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VISIT: <http://mite2016.com>

ISTOCKPHOTO

Meet the CEO of edX, the Online Learning Platform

BY PRACHI PATEL



Anant Agarwal

TECHNOLOGY will play a major role in shaping the future of education. In fact, it already is, according to IEEE Senior Member Anant Agarwal, who helped create massive open online courses (MOOCs).

Agarwal is CEO of edX, which offers more than 1,000 free online courses from universities and other educational organizations around the world. Launched in 2012 by Harvard and MIT, edX is the world's only nonprofit and open-source online learning platform. Those who sign up can find courses on computer science, economics, medicine, physics...just about any subject.

IEEE partnered with edX last year to offer courses in IEEE fields of interest.

A professor of electrical engineering and computer science at MIT,

Agarwal has won MIT's Smullin and Jamieson prizes for teaching—in 2005 and 2010, respectively. He firmly believes in the importance of online education, he says, because it removes barriers, such as cost and location, and improves learning by providing immediate feedback and online collaboration.

"The best way to describe edX is that it's a movement," he says. Here he talks about the creation of edX, the need for online learning, and the future of education.

How did the idea for edX come about?

In 2011 a few technologists and educators at Harvard and MIT realized that while most people in the world could watch videos on YouTube, they were

unable to access higher education content. EdX was designed with three main goals: to make education accessible for everyone, to enhance the learning experience for students both on and off campus, and to further research on education. EdX started with courses from Harvard and MIT and has now grown to more than 100 institutions. The fervor of our mission is shared by those involved.

How is edX, or online education in general, making education more accessible and enhancing learning?

My colleague David Pritchard, a professor of physics at MIT, says that once you're a student sitting past the third row in a traditional classroom, you're getting a distance education anyway. Students submit their homework and get feedback weeks later—or sometimes never. There's no online collaboration. Labs are expensive; many schools don't have them, or students don't get to attempt different versions of experiments.

Online education can fix all these issues and open new avenues for learning. As an example, edX uses active learning, where learners watch short, interactive videos followed by questions, which is proven to improve outcomes. They get instant feedback on homework and exams.

We have really fun gamified labs where students can do, say, a circuits lab with music and virtual interactions. And students are collaborating with and responding to each other in seconds from across the globe. Engaging with people from different backgrounds, ages, and experiences provides additional perspective and helps broaden learners' minds and ideas. These are just some ways in which online classrooms are revolutionizing education.

Has edX met your expectations? Studies have shown that MOOCs have not been effective in getting students to complete the courses.

We have more than met our expectations. In terms of access, we have more than 8 million students since we've launched, with 44 percent from developing countries. Completion rates vary from 5 to 80 percent per course. This depends on the subject and whether the student is enrolled to receive certification or college credit or registers simply to learn more about the topic as an informal learner.

For research purposes, we now have terabytes of data that we capture

from the mouse clicks during every course, and we share this data with researchers. For instance, by seeing how long learners watch a video, where they drop off, and how engaged they are with videos, we were able to determine the optimal length for videos in edX courses. We are also measuring the impact of various teaching techniques based on how students respond to and grasp the subject. Completion rates are not the only benchmark in measuring success.

With that being said, we still have a long way to go.

How might edX be useful to engineers?

Today, there are jobs for the asking in engineering, computer science, and data science. However, graduates don't seem to be getting jobs, and one reason is a skills gap in the latest technologies, like data science. Online education can bridge that gap. We have more than 1,000 courses on subjects including circuits and electronics as well as communication and management. Many engineering students come to edX to learn and acquire additional skills. And many are getting jobs and promotions because of that.

You have won teaching awards at MIT. Do you find teaching online courses just as rewarding as teaching in a classroom?

I've been teaching at MIT for 29 years. To me the most exciting part is seeing a student have an "Aha!" moment. Teaching on campus and online both provide these moments. In some sense, online can be even more rewarding, because you can help thousands of students have "Aha!" moments as opposed to the 50 or so in a classroom.

How do you envision education in the future?

I believe that in-person education alone will be history. All education will become blended, where courses are in classrooms and online or all online.

In a speech at the edX Global Forum, White House CTO Megan Smith said that she expects the future university to be "porous." Imagine that you finish one year completely online, then go to a university to learn for two years, and then you get a job and spread out your fourth year to become a continuous learner. That's an example of a porous university, where you can go in and out. ♦

Tailor-Made Textbooks

IEEE Fellow develops a platform to digitally customize course materials

BY **MONICA ROZENFELD**

AS AN ELECTRICAL and computer engineering professor at Rice University, in Houston, IEEE Fellow Richard Baraniuk became frustrated with the textbooks he was using in the classroom. They were a one-size-fits-all teaching tool, and not all instructors teach a subject the same way. That's when he came up with the idea of digitally customizing textbooks to tailor them for each instructor.

Today, millions of books have been downloaded through Baraniuk's nonprofit OpenStax, which got its start in 1999. They cover biology, economics, physics, psychology, statistics, and other subjects—providing students across the globe with free access to course materials. The platform has enabled college instructors to collaborate from scratch on writing textbooks and other materials.

Those who download the books can customize them further by, for example, rearranging the chapters,

deleting sections, and adding text and links to additional resources.

OpenStax also publishes its own peer-reviewed introductory college and advanced-placement textbooks. And this year it introduced the Concept Coach tool, which provides interactive practice problems to help students understand what they're studying and a dashboard to help them track their progress.

Last year, Baraniuk received the IEEE James H. Mulligan Jr. Education Medal, which recognizes leadership in engineering education.

A NONPROFIT VENTURE

Baraniuk says he was at the right place at the right time for his idea to take off. The World Wide Web was becoming mainstream in the late 1990s, and the software he needed was beginning to take shape.

The original platform, Connexions—now OpenStax CNX—

is an open educational resource platform that allows anyone to author content.

Most contributors are college instructors. OpenStax CNX is similar to Wikipedia. People can add material on a topic and edit one another's contributions. The content is then available as an e-book for free download or to purchase from OpenStax as a print copy for a fraction of the cost of a hard-copy textbook.

At first glance, Baraniuk says, the textbooks on OpenStax might look like any other, but search for a Physics 101 textbook and you'll find nearly 200 versions, each customized to a particular course or institution. Professors and students have learned about the platform mostly through word of mouth, he says. OpenStax also promotes CNX to universities around the world by displaying it at education conferences and making presentations to deans.

Until 2012, most of the materials were for more advanced courses. That year, faculty members from community colleges began to ask OpenStax for introductory textbooks. That's when Baraniuk shifted gears to produce books for more kinds of learners—including preuniversity students studying for college-placement exams and those who

want to learn on their own. And instead of depending on volunteers to write the textbooks, Baraniuk hired experts. To pay for them and other expenses, Baraniuk obtained philanthropic investments from a number of sources including the Bill and Melinda Gates Foundation and the Hewlett Foundation, raising more than US \$20 million.

OpenStax has published 22 textbooks to date. Some 200 people work on each book. The books, in use at nearly 2,000 schools including many community colleges as well as Princeton and Stanford, are also customizable once they're downloaded.

STARTUP MIND-SET

Although OpenStax is a nonprofit, Baraniuk says it operates much like a startup business: "We seek out venture philanthropy, instead of venture capital. The return on investment for funders is not in profits but in student savings."

More than 700,000 students have downloaded the in-house textbooks, resulting in a total savings for them, Baraniuk calculates, of about \$70 million.

OpenStax employs 60 people. Baraniuk, the director, is working on making the business self-sustaining. One way is by building partnerships with companies that offer complementary services such as computer-based homework or tutoring programs. When students sign up for those services, a percentage of the company's revenue flows back to OpenStax.

Concept Coach, with its practice problems is, Baraniuk says, "an extremely exciting next step. The more data we can acquire on how students are learning, the more we can improve student learning."

MOVING, AT LAST

"The education system we're innovating in has not changed in 500 years," Baraniuk says, adding that the system undoubtedly will move forward now that technology is making its way into classrooms [see p. 8]. He says he's ready for the change.

"I marvel at the fact that we were one of the first online education programs," he adds, "and we're one of the few still standing." ♦

This article is part of a series introduced this year featuring IEEE members who have launched their own ventures.



Richard Baraniuk



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