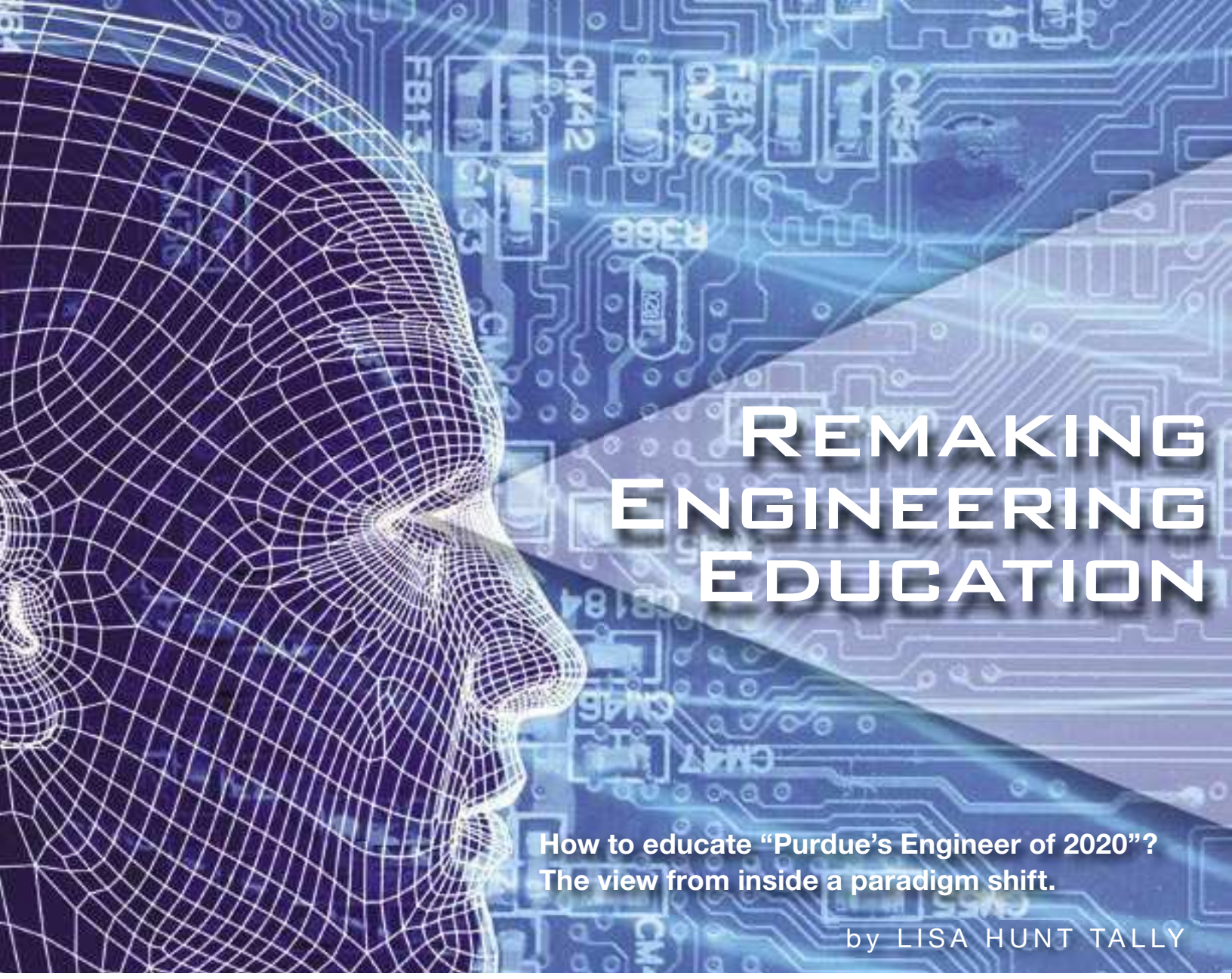


Remaking Engineering Education

How to educate "Purdue's Engineer of 2020"? The view from inside a paradigm shift.

by LISA HUNT TALLY

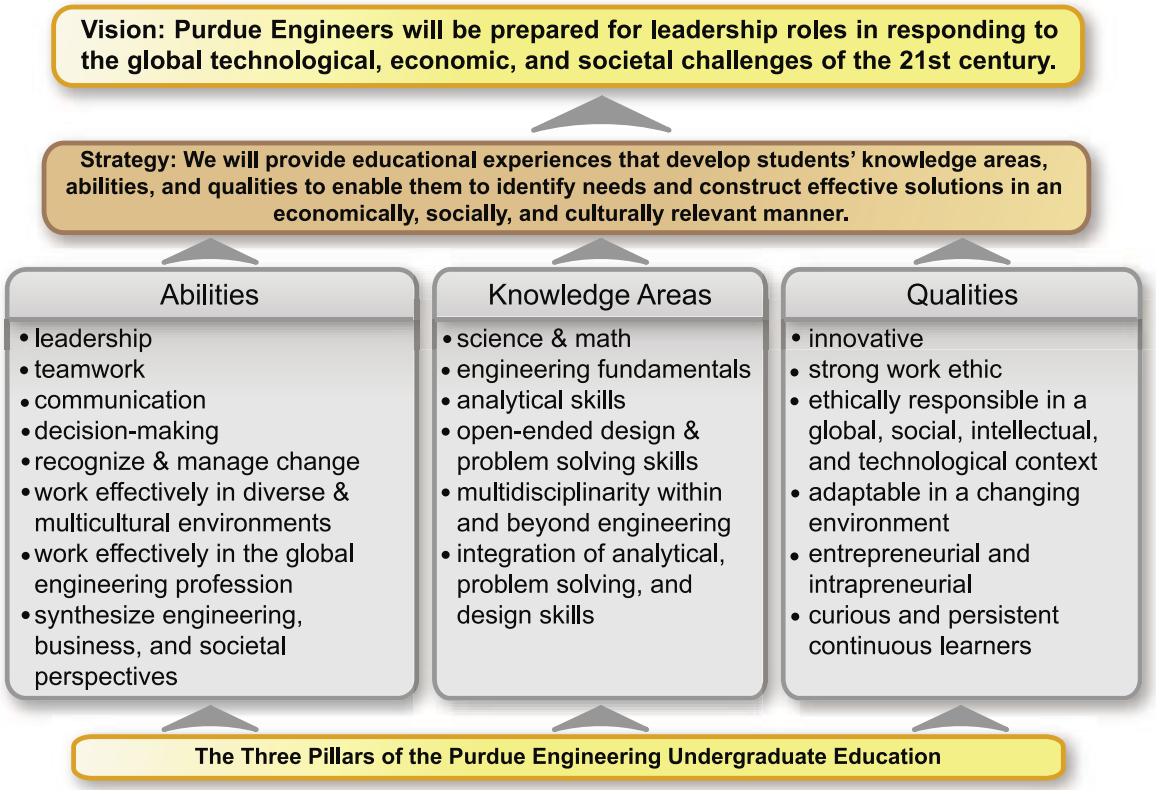
Heidi Diefes-Dux chairs the Department of Engineering Education's graduate program. The department, born in 2004 as the first of its kind in the world, seeks answers to fundamental questions about how students learn engineering: How do they gain conceptual understanding? How can they become lifelong learners? What leads to critical thinking, innovation, and creativity? But, says Diefes-Dux, there are "no books, no curriculum, no precedent." When you're ahead of the academic pack, *you* set the precedent.

Purdue's rapidly expanding Department of Engineering Education is a research engine powering a transformation in how engineering will be taught on campus and, ultimately, around the country. The National Academy of Engineering, the U.S. Council on Competitiveness, and other national organizations are calling for reform—see NAE's report *Educating the Engineer of 2020* and the Council's report *Innovate America*—citing threats to national security and to America's economic competitiveness. Purdue civil engineering alumna Pat Galloway, CEO and chief financial officer of the Nielsen-Wurster Group and former president of the American Society of Civil Engineers, has joined the debate with *The 21st Century: A Proposal for Engineering Education Reform* (ASCE Press), a book painting a global picture in which megaprojects, sustainability, infrastructure security, and multicultural work teams pose challenges for which today's engineers may be unprepared.

At Purdue, the College of Engineering is rethinking engineering education and enacting change—through original research, through curricular reform, through the innovative design of new facilities, and by emphasizing engineering experience, both within the classroom and outside it.

The goal? To educate what Leah H. Jamieson, the John A. Edwardson Dean of Engineering, calls "Purdue's Engineer of 2020." At the heart of the effort is a set of attributes inspired by NAE and articulated by the Purdue Engineer of 2020 Committee.

Purdue's Engineer of 2020



Just who is Purdue's Engineer of 2020? This well-rounded graduate knows engineering fundamentals and the science and math behind them. Readily solves open-ended design problems. Demonstrates flexibility. Has leadership, teamwork, and communication skills. And can work around the world and with diverse colleagues and clients. A "renaissance engineer" of sorts, Purdue's Engineer of 2020 responds to the global technological, economic, and societal challenges of the 21st century—and leaves Purdue's campus prepared to lead (see above).

"It's no longer adequate to have graduates who are strong just in the engineering fundamentals," says Jim Jones, co-chair of the Engineer of 2020 Committee and a mechanical engineering professor. "We're moving toward more of a liberal arts education for engineering." He points to a "dramatic shift" in survey data from Purdue mechanical engineering alumni between 1994 and 2002 on the importance of professional skills.

Identifying the attributes of Purdue's Engineer of 2020 was a milestone, says Jamieson. "We'd never set college-wide goals before," she notes. "And we have a bold vision. Now we're starting to tackle the hard part: how to achieve that vision." Rethinking the curriculum is a big part of the job.

Changing a college curriculum, it's been said, is like moving a graveyard: you never know how many friends the dead have until you try to move them. A National Science Foundation report from 2005, *The Engineering Workforce: Current State, Issues, and Recommendations*, notes, "There has not been a fundamental change in engineering curricula in the United States since the shift to a more science-based engineering education in the 1960s." But Purdue Engineering's leadership is effecting change now; Jamieson has committed $200,000 in seed money in 2007-08 to test new ideas from faculty across the college, with plans to continue to seed innovation in future years.

To prompt faculty members to develop ideas, the college has begun sponsoring an annual Engineer of 2020 workshop focusing on three or four Purdue Engineer of 2020 attributes. On the 2007-08 schedule: entrepreneurship, multidisciplinary learning, and continuous learning. The college hosted a separate colloquium on global issues: the 10th Annual Colloquium on International Engineering Education. "The vision for change is college-wide," says Jones, "but the implementation is by faculty at the school level."

Supporting Purdue's change is a push for facilities that promote teamwork and hands-on authentic learning experiences. The new Neil Armstrong Hall of Engineering, dedicated on October 27 (see page 4), does just that. Housing the Department of Engineering Education, the School of Aeronautics and Astronautics, and the School of Materials Engineering—along with Engineering Projects in Community Service, the Women in Engineering Program, the Minority Engineering Program, and the college's administrative offices—Armstrong Hall is a tangible expression of how the College of Engineering intends to educate tomorrow's engineers.

Take Engineering Education's new "Ideas to Innovation Learning Laboratory," for instance. It's a space where stu-

dents will collaborate on projects from concept to completion. "Engineering is a social exercise—people coming together to create products and processes that profoundly better the lives of individuals around the world," says Kamyar Haghighi, head of the department. "The learning laboratory will offer design-based experiential-learning opportunities in flexible spaces that support and encourage collaborative work."

Aeronautics and Astronautics offers further examples: team learning modules that will benefit students competing for NASA's Reduced Gravity Student Flight Opportunity Program, and lab spaces that include room for teaching and group presentations. Elsewhere on campus, students are benefiting from similarly designed new facilities—the Martin C. Jishcke Hall of Biomedical Engineering, for instance, and the 2004 addition to the Forney Hall of Chemical Engineering. In the future, Mechanical Engineering's planned Roger B. Gatewood Wing will incorporate teaching spaces specially designed by Jones and other ME faculty to promote team learning.

At the core of it all is students' experience of the engineering process. "Students need to practice thinking critically and solving real problems," says Teri Reed-Rhodes, assistant dean for undergraduate education. A focus on experiential learning can make that happen.

Providing experiential opportunities is a Purdue Engineering hallmark—and a continuing mission. Such opportunities include EPICS, a nationally renowned service-learning program founded at Purdue in 1995 (see page 16); co-ops and internships; undergraduate research (see below), and study and work abroad possibilities (see page 16). How to integrate these opportunities and more across the curriculum—and into students' extracurricular lives—is the challenge.

Remaking engineering education is an ongoing process, to be sure, and Purdue's efforts will be honed by research coming out of its Department of Engineering Education (ENE). A pioneering program and a magnet for top talent, the department is providing national leadership in defining this growing field. (Shortly after ENE was established at Purdue, Virginia Tech created a new department of engineering education–and will soon be starting a doctoral program much like Purdue's. Clemson University has just created a new department of science and engineering education.) In fact, the department played a leading role in the recent NSF-sponsored Engineering Education Research Colloquies, which involved 64 STEM (science, technology, engineering, and math) scientists and scholars—13 from Purdue—from institutions across the U.S. who collectively defined five broad research categories: Engineering Epistemology, Engineering Learning Systems, Engineering Learning Mechanisms, Engineering Diversity and Inclusiveness, and Engineering Assessment. A report

SURF

Summer Undergraduate Research Fellowships

This past summer, undergraduate students from around the world converged at Purdue to pursue hands-on research projects. Their goals? To study new ways to transform coal into liquid fuels. To develop instructional technology in first-year physics education. To increase the efficiency of solar cells. To design and test radio-frequency antennas. And more.

Through Purdue's Summer Undergraduate Research Fellowship program (SURF), 56 students from universities in Australia, Austria, India, Ireland, Serbia, Switzerland, and Turkey joined some 130 Purdue students in working directly with Purdue professors and researchers, employing tools used on the cutting edge of science, engineering, and technology. Participants spend the summer on campus, earning a $1,000-per-month stipend. The experience enhances students' classroom learning, involves them in real problem solving, and sparks interest for research careers in science and engineering.

"Most undergraduate students don't have the opportunity to do this type of research," says Jay Gore, Purdue's Vincent P. Reilly Professor in SURF, which got its start in 2003. "The goal is to introduce undergraduate students to the concept of graduate and post-graduate research projects and have the opportunity to be mentored by university professors and researchers."

Purdue students who want an off-campus experience: the Research at Federal Labs Program. And beginning in 2008, SURF will offer a year-round research program for students at Purdue.

—L.H.T.

on the colloquies and details of those research areas were published in the *Journal of Engineering Education* last year.

"This was a tremendous accomplishment," says Haghighi, "since it was the first major collective attempt of the engineering education research community to develop a cohesive and comprehensive national research agenda that will serve as a guide and framework, particularly at a time that this community is establishing engineering education as a serious and scholarly discipline."

Purdue ENE faculty members like Ruth Streveler are digging deep to answer such questions as, What important engineering science concepts do students find difficult? How can you design learning environments that help students better understand these concepts?

"Our research shows that as many as 25 percent or more of advanced engineering students have a faulty understanding of fundamental concepts in their field," says Streveler. For instance, many chemical engineering students confuse equilibrium and steady state, electrical engineering students may understand voltage to be a property of a particular single location, and mechanical engineering majors may think of force as the property of a body. These flawed views hinder a student's ability to understand engineering problems deeply.

Streveler is currently refining a thermal and transport concept inventory, which measures student understanding of fundamental concepts in fluid mechanics, heat transfer, and thermodynamics. She also plans to begin research on why certain engineering concepts are difficult—in hopes of providing insights into how to design learning environments that truly transform students' educational experience.

Such abstract insights should find their way into concrete practice at Purdue, says Jamieson. The College of Engineering will become ENE's testbed for ideas, with Purdue students the beneficiaries. ENE's reach extends to younger students as well: the department's INSPIRE program (see box at right) connects with P–6th grade teachers to expand their view of engineering and, in turn, excite youngsters about the field. (Similarly, EPICS High is working with high school teachers to bring community-based engineering design into high schools.)

From this kind of seminal research to cutting-edge facilities to innovative learning opportunities, when you take a look at Purdue Engineering's educational initiatives, you see a paradigm shifting. At this moment in the history of how we educate engineers, to remain static is to become obsolete. The push is on to educate Purdue's Engineer of 2020. Stay tuned as Purdue Engineering educators, researchers, and leadership rethink, refine, and remake engineering education to equip that engineer to thrive.

INSPIRE

The Institute for P-12 Engineering Research and Learning

Founded in 2006, INSPIRE conducts basic multidisciplinary research in human cognition and concept development in engineering education.

The institute, a centerpiece of Purdue's Department of Engineering Education, aims to inform, at the national level, the design of engineering curriculum, student learning environments, and teacher education—all to motivate new generations of pre-college students to embrace engineering.

To ensure broad impact, INSPIRE is initiating and leading an advocacy effort at state and national levels to influence policymaking that will increase the United States' commitment to P-12 engineering education. And to engage teachers, the institute's Summer Academy program offers P–6th grade teachers a week of intensive hands-on training and assistance in developing personalized engineering lesson plans.

"I learned two very important facts by 8:30 a.m. the first day of training," says Summer Academy participant Sandy McMahon. "[First], that I knew absolutely nothing about engineering, and [second], that engineers and teachers don't think alike." It wasn't easy introducing her to the world of engineering, she adds: "I have been challenged every minute of every day,... [but] the staff at Purdue has been phenomenal."

—REBECCA GOLDENBERG