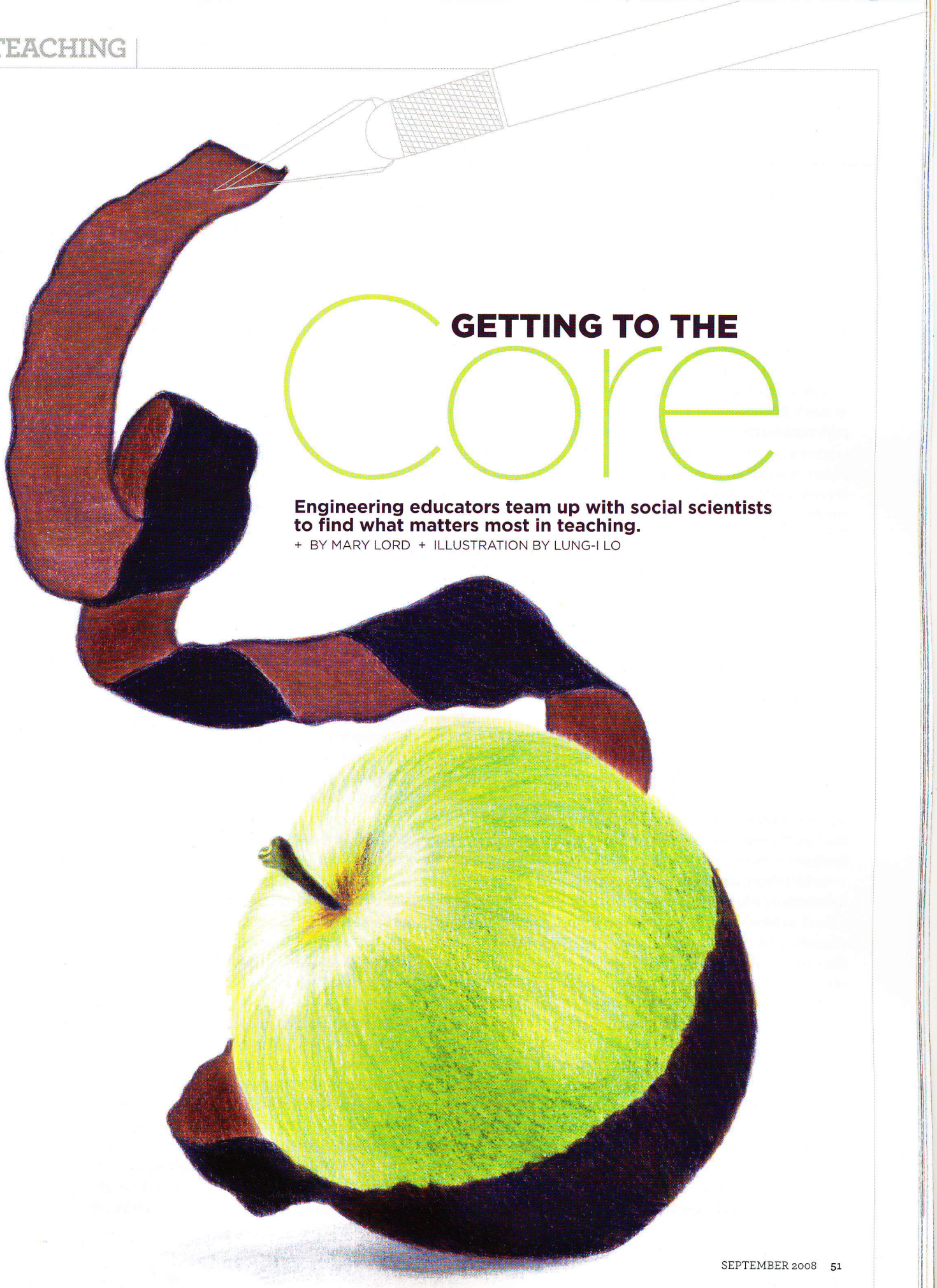


GETTING TO THE Core

Engineering educators team up with social scientists to find what matters most in teaching.

+ BY MARY LORD + ILLUSTRATION BY LUNG-I LO

Engineers are practical, hands-on problem-solvers for whom nothing is beyond improvement. Except, perhaps, when it comes to engineering education. And that frustrates civil engineering professor and education researcher Karl Smith.

"We're continually trying to find better, cheaper, safer, less harmful, more energy-efficient ways to do things," observes Smith, a professor at Purdue University and the University of Minnesota. "Yet we don't use an engineering approach to engineering education!" As a result, too many classes "look like they did 100 years ago."

Smith and his research partner Ruth Streveler, assistant professor of engineering education at Purdue, are working to alter that mindset with hard evidence from the social sciences. Dubbed Rigorous Research in Engineering Education, or RREE, this new paradigm pairs number-crunching engineering faculty with peers in education, psychology or other qualitative-friendly fields on robust, interdisciplinary research projects. The goal: system-wide reforms that will improve curricula and teaching methods while fostering skills that engineers need to succeed, including the ability to work in teams, think creatively, communicate ideas and become self-directed learners. Funded by the National Science Foundation, RREE has evolved rapidly from workshop sessions to pioneering practice involving some 150 scholars from 72 institutions.

Open-ended QUESTIONS

Unlike much engineering education scholarship, which focuses on individual classrooms or a particular curriculum, RREE asks broader questions, probing how students think about and learn engineering. What do they find difficult? If they decide to drop engineering, why? Partnering with educational psychologists or other "mentors" enables engineering faculty to develop open-ended surveys and assessments that tease out answers.

In 2004, Smith and Streveler approached their first RREE workshop for educators with some trepidation, anticipating that it would be difficult to attract engineering instructors. For one thing, education research doesn't count toward tenure on most engineering faculties. Moreover, engineers tend to dismiss educational research because "it isn't real engineering," notes Smith.

Their worry proved misplaced. Two hours after posting a notice on the deans' list-service of ASEE, a co-principal investigator, they had 85 applicants for 20 slots. The workshop was held in Golden, Colo., home of the Colorado School of Mines, where Streveler was the founding director of the Center for Engineering Education. Over five intense days, participants got a crash course in the science and principles of how students learn – particularly how they learn engineering. Led by three facilitators, one each from ASEE, the American Educational Research Association, and the Professional and Organizational Development Network in Higher Education, engineering faculty explored the psychological and cognitive science of learning and its impact on curriculum design. They learned how to parse educational research articles, link theory to practice, and investigate ideas and trends in engineering education. For their capstone project, participants and their assigned collaborators had to come up with a big-picture question then design a small research study to answer it. One indication RREE had struck a chord: even after an exhausting first day, the engineers remained in the room to brainstorm ideas with their colleagues and mentors.

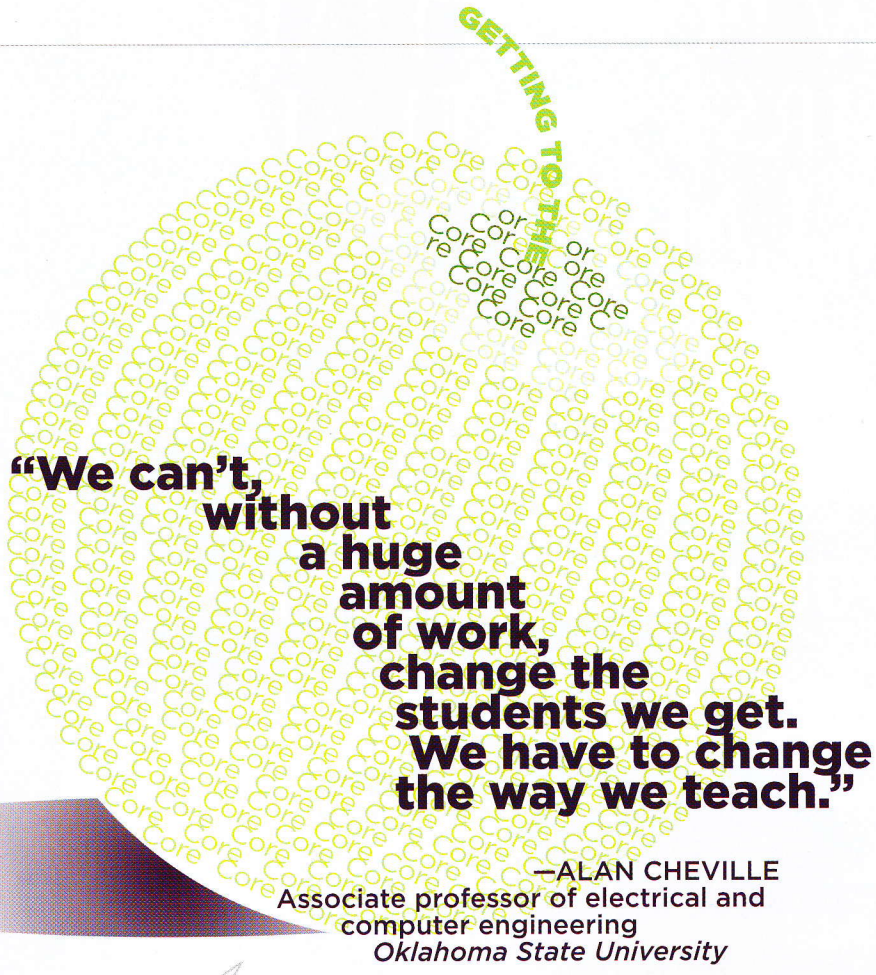
There was some skepticism at first. Alan Cheville, associate professor of electrical and computer engineering at Oklahoma State University, Stillwater, took to "reading all the literature with an eye to proving it wrong." Instead, his "whole thinking started changing." Together with an education specialist at Michigan State University, he dramatically reconfigured his capstone design course around a new taxonomy of design skills and "authentic experiences." Along with core content, his students now also must learn to communicate – by winning approval for their projects, then creating posters or another form of advertisement to "sell" them. Cheville modifies the course each semester based on student feedback. "We can't, without a huge amount of work, change the students we get," he concludes. "We have to change the way we teach."

A Trove of DATA

Having an educational psychologist help frame questions and guide the research was one of the biggest workshop benefits for Donna Reese, associate dean of academics and professor of computer science and engineering at Mississippi State University's Bagley College of Engineering. Instead of finding out what students learn, participants were guided to probe how and why they learned. Reese's project sought to investigate why students abandoned engineering. She surveyed those who had left but were still enrolled at Mississippi State. "I wasn't big on these open-ended questions," recalls Reese. "As any engineer, I wanted something I could average." Her mentor, however, encouraged her to solicit comments that went beyond answers to specific questions.

Following this advice yielded "a lot of rich data" Reese wouldn't have obtained had the queries been narrowly focused. While the findings were "nothing earth-shattering," Reese says, "the fact that I could say these are our students, these are Mississippi State students who left, and this is what they're telling us about our engineering program, was very powerful." Among other things, the responses highlighted the leavers' sense of not belonging, prompting Reese to create a special "living/learning community" for engineering undergraduates in an old dormitory, replete with pizza parties with professors, older student mentors to commiserate with over calculus, and bowling parties.

For Julie Trenor, RREE has been nothing short of a "career-changing experience." While in a non-tenure track position at the University of Houston's Cullen College of Engineering, the then-director



of undergraduate recruitment worked on a number of projects with mentor Shirley Yu, an associate professor of educational psychology there. Their study of female engineering students' experiences led Trenor to reorganize her introductory engineering course, including giving students more time in class to work on projects and hosting a "get involved" fair so freshmen could easily learn about and join engineering organizations. The RREE training helped Trenor land two major National Science Foundation grants, write several studies for publication – and catch the eye of Clemson University, where she became an assistant professor in the department of engineering and science education in August.

Fledgling RREE-sponsored collaborations have inspired other changes, as well. In researching what concepts students found difficult in an introductory electrical circuits course, CSM lecturer Ravel Ammerman discovered "robust misconceptions" about voltage and current. Students thought of them as substances rather than processes involving electric charge, failing to grasp the risk of shock and other hazards. So he revamped his curriculum, cutting back lectures, adding a safety segment, and giving students more time to practice what they learned. Stephanie Ivey, an assistant professor of civil engineering at the University of Memphis, researched learning styles and found that students had a strong preference for visual as well as hands-on learning. She and her collaborators seized on geographic information systems as offering both a good visual tool and a way to develop students' analytical skills. They developed a GIS lab, complete with global positioning satellite equipment and software, and found ways to work in GIS/GPS applications throughout the civil engineering experience.

Participants are also publishing studies – and attracting funding. Meanwhile, engineering education centers have sprouted at schools across the country, from Virginia Tech to Utah State. "We're growing a new field," explains Leah H. Jamieson, dean of Purdue's college of engineering, whose school is the first in the nation to elevate engineering education to a department. She feels strongly that scholars must translate their research "into impact beyond publishing a paper."

Curriculum RESHAPED

At Purdue, this philosophy is apparent, with RREE helping to reshape what and how engineering gets taught. To prepare engineers for leadership roles in the 21st century global economy, the college's new 2020 curriculum stresses hands-on, multidisciplinary learning experiences designed to foster teamwork and communication alongside science and math knowledge. "The ultimate test" of RREE, says Jamieson, is "how to take the results of this rigorous research and put it into practice."

Streveler and Smith intend to do just that. They are studying 50-page pre- and post-workshop surveys to gauge the program's impact. "We tried to practice what we are preaching," says Smith. Early analysis reveals that participants had changed how they taught in order to improve student outcomes. Several have published papers. And all intended either to continue working with their collaborator or to find a collaborator on campus or at another university. "It's not the actual results of the research that are the most valuable," explains Trenor, "It's the collaborations that I've been able to develop and the understanding of how rigorous research is done." She calls the improvements to her introductory engineering course "a pleasant by-product" of the new lens she has gained on education.

Transforming engineering education is a journey, not a destination, and Streveler and Smith hope more faculty members will join them for the ride. Their next phase includes building a more active online presence for RREE, including social networks and Web-based seminars, plus a long-term evaluation of the program. In the meantime, they have been recommended for NSF funding for a follow-up project. Interested engineering educators are welcome to contact them and explore the RREE frontier.

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