As chair of the Department of Mechanical Engineering, I’m proud of how we fully immerse our students in hands-on learning experiences throughout our entire curriculum.

Employers are clear: They want graduates with hands-on experience and a demonstrated ability to work in teams, design and build prototypes, and solve problems in laboratory settings. This is exactly where our students excel, and as we move toward a new “design-plus” education model, our students not only design solutions to real-life problems, but also gain the laboratory-enhanced experiences they need to complete a degree.

Hands-on engineering is the core of our four undergraduate specialties: energy systems, mechanical systems, manufacturing systems, and design and innovation in engineering. Students have access to excellent machining facilities for building prototypes. They participate on multiple award-winning vehicle design teams. And in their courses, they have unparalleled access to real-world design challenges.

For example, every year we graduate nearly 200 mechanical engineers who have direct training in and experience with manufacturing. Many of these students participate on projects with industry connections, particularly working through our world-renowned Polymer Engineering Center. And dozens of students annually develop real, meaningful solutions for people with disabilities through our UW-CREATe program.

By integrating design and research experiences across our curriculum, we’re producing graduates who can make immediate contributions in the workplace. They are team-oriented, creative problem solvers who are truly prepared to tackle the challenges of today and of the future.

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Every spring, mechanical engineering students in design courses exhibit and demonstrate their prototypes during the Undergraduate Research and Design Symposium.

From left: Seniors Dan Bocke, Nathan Beilke, Meagan Collins and Alex Vanderheydan designed a tricycle for 4-year-old Ronan King (center), whose disability prevents him from steering a conventional tricycle. Instead, he can push down on levers next to the seat to turn the tricycle left or right.
A strong future: Nanotechnology in alloys gives manufacturers a big boost

For companies that manufacture large specialty vehicles, lighter materials can give their products a competitive edge. Lighter materials take less energy to move—saving fuel, reducing greenhouse gas emissions, and more practically, reducing wear and tear on engines.

Metals such as aluminum and magnesium are promising for strong, light components, but there’s a problem: Some of the strongest alloys of these metals are difficult to cast. Very often, they crack as they cool from a liquid state, making commercial-scale production of parts unfeasible.

Professor Xiaochun Li directs the UW-Madison Nano-Engineered Materials Process Center, in which more than a dozen scientists are adding a new element to manufacturing processes. Nanoparticles, or tiny clusters of substances such as silicon carbide or aluminum oxide (alumina), can improve the properties of materials. By adding these nanoparticles to a melt of aluminum alloys, then using intensive ultrasonic waves to disperse and distribute the nanoparticles evenly, researchers can increase the structural integrity of light metals and overcome the problem of hot cracking as aluminum and magnesium alloys solidify.

In order to bring these alloys to market in a practical way, Li is working on scaling up the process. Current methods are expensive and difficult for large foundry systems to implement, but Li’s process, which he is testing on an industrial level at places like Eck Industries in Manitowoc, Wisconsin, can be scaled up more easily.

Although solidification-based nanomanufacturing—for example, through casting—takes place at very high temperatures, nanoparticles need to be processed at temperatures low enough that they don’t burn up. To solve this problem, Li’s team is using semi-solid melts of the alloy to capture and disperse the nanoparticles. Once the researchers create this “master” nanocomposite, using 5 to 10 percent nanoparticles, they can mix it into the pure alloy to produce a more lightweight final product.
For plastics expertise and education, UW-Madison engineers excel

“UW-Madison is well-known for its industry partnerships, leading-edge research and plastics courses integrated into our mechanical engineering degree program,” says Kuo K. and Cindy F. Wang Professor Tim Osswald.

The polymer engineering research and educational program at UW-Madison is among the oldest and most respected in the United States. It dates back to 1946, when mechanical engineer Ron Daggett began teaching plastics processes courses. At the same time, John Ferry, a chemistry professor at the university, made key research contributions in polymer physics, while chemical engineer R. Byron Bird linked the two fields with fundamental discoveries in polymer fluid dynamics and rheology. With UW-Madison chemical engineers Warren Stewart and Edwin Lightfoot, Bird authored the landmark 1960 textbook, *Transport Phenomena*.

Today, the UW-Madison plastics faculty includes international experts in plastics rheology, injection molding, moldless manufacturing techniques, plastics simulation, and biomedical applications for plastics, among others. Through the Polymer Engineering Center Industrial Consortium, they collaborate closely with industry partners ranging from multinational companies to Wisconsin businesses such as Phillips Plastics Corp. of Hudson, Bemis Manufacturing of Sheboygan Falls and Extrusion Dies Industries of Chippewa Falls. “We’ve always kept our eye on industry and know the industry’s needs,” says Osswald.

Many of those local and international companies have their roots in plastics undergraduate and graduate education at UW-Madison, where faculty literally wrote the textbooks in use worldwide on polymer engineering. Osswald alone is author of 12 books, among them *Materials Science of Polymers for Engineers*, *Understanding Polymer Processing*, and the *International Plastics Handbook*, and faculty use technologies such as video and podcasting to meet students’ educational needs.

In addition, UW-Madison students learn about plastics and put that knowledge to the test in an operational polymer laboratory that houses more than a dozen state-of-the-art polymer-processing machines. “We have nearly 100 kids coming out of the department every semester who understand plastics—and that’s unique,” says Osswald. “Not many schools have that.”

The polymer faculty also extend their knowledge far beyond the university’s walls. For example, in early 2012, Osswald and faculty from the University of Massachusetts, Lowell, signed a memorandum of understanding with the PlastIndia Foundation to develop curriculum for the PlastIndia International University. Dedicated to plastics research, higher education, management and entrepreneurship and expected to open by 2015, the new university will be located in the state of Gujarat, one of the largest plastics manufacturing regions in India.

“The contributions by your esteemed university in the field of polymer engineering are second to none,” says Bipin M. Shah, vice president of the PlastIndia Foundation. “Thus, we selected UW-Madison. India needs education from very preeminent scholars for continuous growth, where hands-on training as well as processing knowledge of polymers is a must.”
The mechanics of stronger bones

As human bones age, they undergo geometric changes and also lose minerals such as calcium that give them density and strength. As a result, broken bones are one of the most common injuries in older people, and nearly 300,000 Americans are hospitalized each year for hip fractures alone. With fractures often come permanent losses in mobility. “As we age, these are problems many of us face,” says Associate Professor Heidi-Lynn Ploeg, director of the Bone and Joint Biomechanics Laboratory.

Working with a team of five graduate students, Ploeg is studying the mechanics of the human skeleton, with the aim of improving bone health for everyone—from infants with congenital defects to trauma victims and the elderly.

While other bone research might occur at the cellular level, Ploeg focuses on tissue, studying the mechanics of tissue strength and how her samples respond to pressure. Studies already have found that people can strengthen their bones—and keep them stronger—with a combination of exercise that puts stress on their bones, good diet, and hormone treatments. But the details of how best they can combine those solutions to create recommendations have yet to be defined.

For example, there’s currently no way to directly measure a bone’s strength in a living human. CT scans and MRIs can reveal mineral content—but more mineral deposits don’t necessarily indicate stronger bones, and even drug treatments that add minerals to weak bones might still not strengthen them.

Using samples taken from patients undergoing hip replacements and a unique bioreactor that keeps those hip bone samples alive for weeks, Ploeg and her team can directly test how the tissue responds to different amounts and types of stress. Since response to stress depends on the strength of the bone, she can use that data to determine what exercise, such as lifting weights or walking, and how much of it, can help stimulate new bone growth.

By combining the application of stress with different levels of hormones, Ploeg can optimize the mix of exercise and hormone treatment, and create precise recommendations for bone loss prevention, as well as physical therapy programs.

None of these conclusions would be possible without the live bone...
samples, whose preservation, thanks to innovative sample preparation and a mix of good nutrition, temperature and protection from disease, has been an exciting new development. “The success so far is the process, and the unique experiments we can run as a result,” says Ploeg, who collaborated with colleagues in population health science to develop the bioreactor. “It’s very exciting to us that you can keep a human bone alive for seven weeks and run experiments on it.”

In other research, Ploeg also is studying the scale of an entire bone for such applications as bone-lengthening or deformity-correcting devices that can rest just outside a bone. What’s currently available must either go through the middle of a problematic bone, or rest as a cumbersome device outside the patient’s skin.

In perhaps as few as five years, she hopes to have results and products ready for clinical use. “I’m very excited about the potential of our research to benefit patients,” she says.
Professor Rolf Reitz (above, wearing tie, pictured with grad students Reed Hanson, Derek Splitter and Sage Kokjohn) and (below) Assistant Professor David Rothamer, Grainger Professor of Sustainable Energy Jaal Ghandhi and Associate Professor Scott Sanders are among seven ME faculty who conduct research via the ERC.
Engine research for a cleaner future

The future of clean, efficient transportation is emerging at UW-Madison, where a team of faculty, staff and students explores the fundamentals of spark-ignition and diesel engines and leads the nation in low-temperature combustion and innovative dual-fuel systems research.

In an era of tightening fuel supplies, rising costs and increasingly sustainability minded institutions and industries, finding more efficient ways to transport passengers from point A to point B is an important enterprise.

Centered around the research of seven mechanical engineering professors, the Engine Research Center (ERC) is the largest of its kind in the United States. It continues a long tradition of engine research on campus, which began with engine combustion temperature research in a metal shack in 1946.

Now, with more than $3 million in research expenditures per year and more than 50 students conducting research projects, the center is a leader in the effort to understand combustion, improve engine efficiency, and reduce emissions.

ERC researchers use detailed supercomputer modeling to predict engine function. They also create and use advanced laser-based diagnostics to provide detailed validation data for models, and explore combustion beyond the scope of modeling efforts. They have a wide array of facilities for optical measurements, more than a dozen test engines, and extensive computational capacity.

Center researchers have pioneered an array of innovations, such as computer models that commercial software vendors have adapted and now sell to companies around the world for engine design—a solution more cost-effective than engine testing.

Professor David Foster was the first to successfully demonstrate four-stroke homogenous charge compression ignition (HCCI) engine operation, which mixes diesel and gasoline in a reaction with the efficiency of the former and the clean emissions of the latter. Professor Rolf Reitz is in the process of developing a variant, called reactivity controlled compression ignition (RCCI), that allows for more control over the combustion process. RCCI could improve diesel efficiency by as much as 15 percent, and can emit up to 75 percent less toxic nitrous oxide, without the need for expensive exhaust after-treatment.

In January, U.S. Department of Energy Secretary Steven Chu said the center’s low-temperature combustion research could considerably improve engine efficiency and increase the fuel economy of light-duty vehicles by more than 50 percent.

Collaboration drives more than half of the center’s funding, with major industry partners that include: General Motors, Caterpillar, and Ford; campus collaboration with the Wisconsin Small Engine Consortium and the 30 member companies of the Diesel Emissions Reduction Consortium; plus, federal partnerships with the National Science Foundation and Sandia National Labs.

“The majority of the ERC research funding comes from industrial sources, which is a testament to its value to the engine industry,” Reitz says.
Getting a head start on design

When sophomores and juniors take a new design and prototyping course in the fall of 2012, their experiences will tie together a curriculum already strong in manufacturing and engineering math and science, and rich in informal hands-on prototyping experience. The course augments the opportunities students have to get hands-on experience. It bridges the gap between introductory engineering courses for freshmen and senior design courses, ensuring they learn to use machining tools earlier in their undergraduate careers.

Students in the college already have a wealth of informal opportunities to create prototypes that will eventually guide new product conceptualization and testing. Not only do they learn specific hands-on skills in more specialized courses, but they can also flex their design muscle in independent study projects—often their first chance to start feeling out potential graduate work—and competitive vehicle projects like the award-winning clean snowmobile and hybrid vehicle teams.

Now, students have an additional chance to learn a broad range of fundamentals through an experience-heavy lab course that will start them with lightweight foam models and progress through wood shop, sheet metal, rapid prototyping instruction, and designing and constructing a Sterling engine.

And more than just building prototypes, students learn to take the necessary pragmatic approach to materials selection and tolerance specifications—for example, what’s the most cost-effective choice, while still accomplishing the goal?

“One thing we emphasize specifically in this course,” says Associate Professor Frank Pfefferkorn, a design instructor, “is you build a prototype for an explicit reason and you identify that reason.”

Prototyping is a fundamental skill for would-be mechanical engineers, regardless of their career goals. In making prototypes, Professor Jay Martin says engineers try to understand what a product looks like at its simplest level and how users interact with it, but also to address more precise questions: does it move as designed, how much friction do moving parts generate, how much load can it bear?

To support this hands-on learning, the well-stocked student shop, which students can work in as soon as they become certified, has dozens of pieces of equipment, from ordinary mills and lathes to sophisticated computer-aided mills and 3-D printers. Combined with comprehensive welding, sheet metal, and CAD/CAM labs, plus equipment in
faculty labs, students have access to tools that will enable them to machine nearly anything, in any material, including intricate metal parts. Rapid prototyping machines also are available to students, including a new laser sintering machine capable of “printing” both plastic and metal parts. They offer students the chance to get a head start on exciting trends in prototyping and manufacturing alike.

And in addition to the shop, young engineers have the opportunity to work in the rapid prototyping and electrical shops of the Advanced Fabrication Laboratory at the Morgridge Institutes for Research—a state-of-the-art facility that R&D Magazine named the 2012 Lab of the Year—and in local businesses such as consulting firm Design Concepts.

Also nearby is the university’s Physical Sciences Laboratory, a research and development lab that offers a range of consultation, design, fabrication and calibration services.

“We have three quite remarkable places right there,” Martin says.

In addition to the breadth of its more commonly used facilities, the college still has its foundry for casting molten metal. The foundry, once a common fixture of engineering campuses around the country, has become a unique opportunity as other campuses have retired theirs.

And there are big plans for the future: The department is unrolling a series of enhancements to its design curriculum over the next several years, adapted to Wisconsin’s uniquely collaborative approach.

Those plans include both an interdisciplinary capstone design course sequence that combines engineering students and students from other disciplines such as business—and provides them a new space for design and prototyping to allow them to work together on projects.

“Our new prototyping course is just the first part of that,” Martin says.
Consolidated Papers Professor of Controls Engineering Bob Lorenz received the 2011 Distinguished Service Award from the Institute of Electrical and Electronics Engineers (IEEE). The award recognizes his dedication and exceptional service to the IEEE Industry Application Society.

Professor and Vilas Scholar John Moskwa received the American Society of Mechanical Engineers Charles Stark Draper Innovative Practice Award for his development of high-bandwidth transient engine test systems using advanced electronics and hydrostatics. Moskwa also received the Society of Automotive Engineers 2012 Edward N. Cole Award for Automotive Engineering Innovation. The award recognizes his work in developing an improved transient test system for engine R&D using a single-cylinder research engine.

Wisconsin Distinguished Professor Rolf Reitz received the American Society of Mechanical Engineers 2011 Internal Combustion Engine Award. Reitz was recognized for his long-term contributions to the physics of liquid fuel spray atomization, 3-D numerical modeling of combustion, and combustion system optimization.

Assistant Professor David Rothamer received the National Science Foundation 2011 Faculty Early Career Development Award (CAREER) to investigate a new diagnostic technique that uses light-emitting phosphors to measure the temperature of a low-temperature combustion reaction throughout the entire process.

Senior Lecturer Jay Samuel received the American Society of Mechanical Engineers (ASME) Outstanding Student Section Advisor Silver Medal Award for 2011. Samuel has been the ASME student section advisor at UW-Madison for 18 years.

INTERNATIONAL

Kuo K. and Cindy F. Wang Professor Tim Osswald was named Honorary Professor by the National University of Colombia, recognizing his contribution to the advancement of the university’s academic environments.

Phil and Jean Myers Professor David Foster received the Academic Contribution Award from the Japanese Society of Automotive Engineers in honor of his collaboration with Japanese visitors to Madison and longtime connection to Japan.

Professor John Pfotenhauer was named Qiushi Lecture Professor by the Zhejiang University of China. The university created the position to invite significant Chinese and international scholars to enrich the university’s educational community by promoting training, research and development in the science disciplines.
PAPERS

- Pulsed laser micro polishing: Surface prediction model received the 2011 Outstanding Paper Award at the sixth International Conference on Micro-Manufacturing. The paper was authored by graduate students Madhu Vadali and Chao Ma, Professors Neil Duffie and Xiaochun Li, and Associate Professor Frank Pfefferkorn.

- Investigation of supercritical fluid-laden pellet injection molding foaming technology (SIFT), by Xiaofei Sun, a PhD student under Professor Lih-Sheng (Tom) Turng, was named the best graduate student paper in the injection molding division at the 2012 Society of Plastics Engineers annual conference.

NOTEWEIGHTY

- Cool-It, an interactive game developed for Professor John Pfotenhauer's cryogenics course, received second place in the interactive category of the Association for Educational Communications and Technology Multimedia Production Division Immersive Learning Awards. The game allows students to solve real-life cryogenics problems, such as designing coolers for minesweeping devices.

Associate Professor Dan Negrut (pictured with Professor and Chair Roxann Engelstad) received the College of Engineering Harvey Spangler Award for Technology-Enhanced Instruction to recognize his innovative internet-based course. The course allows students to learn remotely at their own pace—and at the same time gain hands-on experience with supercomputing clusters to acquire increasingly in-demand skills needed for large-scale modeling and simulation.
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Together we can make a difference!

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