Iowa State University
College of Engineering

CYCLONE ENGINEERING RESEARCH

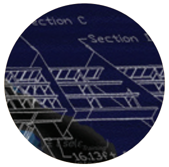
Cyclone Engineering Research

The faculty at Iowa State's College of Engineering transforms the results of scientific research into engineering accomplishments. We emphasize a collaborative, interdisciplinary research approach that centers around five signature areas:

Biosciences & Engineering

Molecular biology, bioinformatics, biochemistry and veterinary medicine come together with engineering to create research activities in areas such as nanovaccines, cancer and infectious disease treatments, and nerve damage and brain injury recovery.

Critical Infrastructure



A cross-disciplinary initiative between engineering departments combined with centers like the Institute for Transportation (InTrans), Center for Non-Destructive Evaluation, Information Assurance Center, and Wind Simulation and Testing Laboratory results in solutions to secure the nation's economy, security and health.

Energy Sciences & Technology

Seamless interactions and collaborations with the U.S. Department of Energy's Ames Laboratory and centers supported by the state and other funding sources help advance faculty programs already well established in energy production, sustainable energy and energy storage.

Information & Decision Sciences

Now that advancements in technology have given engineers access to more data than ever before, researchers at Iowa State continually look for meaningful ways to use this information through programs in cyberinfrastructure, bioinformatics and computational biology and by utilizing the high-performance computing facilities on campus.

Sustainability

Iowa State's strength in areas like agricultural engineering, statistics and agricultural economics, along with established groups including the Bioeconomy Institute, Center for Sustainable Environment Technologies and NSF Engineering Research Center for Biorenewable Chemicals, results in robust research programs dedicated to creating a sustainable bioeconomy.

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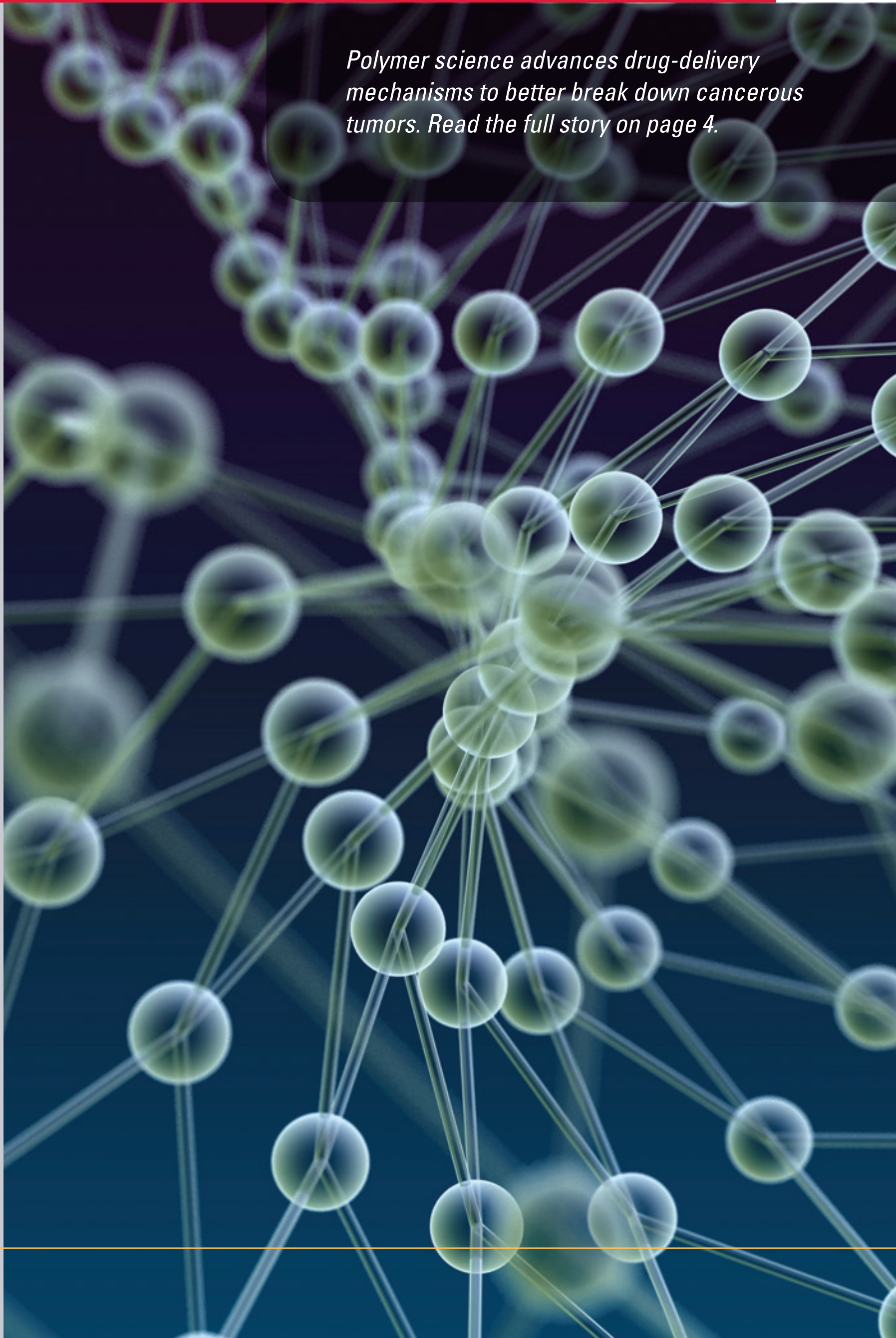
A GLOBAL REACH

The vibrant, innovative environment at Iowa State's College of Engineering goes beyond our backyard to across the world.

With our faculty working on projects ranging from underground sensors that provide valuable insight into sustainable agriculture to new techniques that introduce accelerated bridge construction into seismic regions, enjoy a glimpse of the ways our engineers are making a difference:



Polymer science advances drug-delivery mechanisms to better break down cancerous tumors. Read the full story on page 4.

Katie Bratlie (right), assistant professor of materials science and engineering and chemical and biological engineering, and **Rachel Philiph**, senior in materials science engineering and Goldwater Scholar, work together in Bratlie's lab.

CHANGING CANCER TREATMENT

Polymer science advances drug-delivery mechanisms to better break down cancerous tumors

The National Cancer Institute has indicated that in 2014, "it is estimated that there will be 1,665,540 new cases of all cancer sites and an estimated 585,720 people will die of this disease."

That's why **Katie Bratlie,** an assistant professor of materials science and engineering and chemical and biological engineering at Iowa State University, wants to create a more effective and efficient way to treat the disease. And so she is developing biodegradable polymers to improve chemoimmunotherapy—a type of chemotherapy that works with the immune cells to remove cancerous cells.

The immune cells she's working with are white blood cells called macrophages. Found all across the human body, macrophages are considered the "first responders" to bodily injuries, removing bacteria and debris.

Despite being good for the rest of the body, macrophages in tumors make the prognosis for cancer patients much worse. That's because these cells promote blood vessel growth, bringing nutrients to the tumor and helping it grow.

"Once those blood vessels are established, the tumor cells have a place to metastasize across the body," explained Bratlie. Macrophages offer an advantage in that they take up drugs relatively easily, making them a great resource for Bratlie, who is determined to find a way to utilize the proprieties of tumor-associated macrophages for treating cancer.

She and her team are looking at a variety of chemical characteristic groups to uncover a functional group that will alter macrophage secretion profiles, essentially reprogramming the macrophage cells to act in a pro-inflammatory capacity, fighting off the tumor rather than promoting its growth.

When she finds the ideal polymer, she plans to integrate it into a hydrogel that will encapsulate a cancer-treating drug. Her technique would allow the medicine to be delivered directly to a growing tumor without impacting surrounding cells.

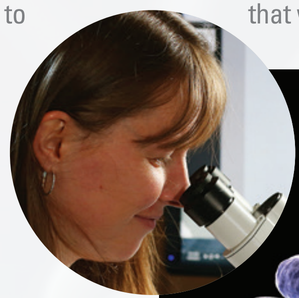
"Using this approach, the drugs used to treat a cancer will attach to a malignant cell and signal to macrophages and other white blood cells that the cancerous cells should be phagocytosed, or digested," she explained.

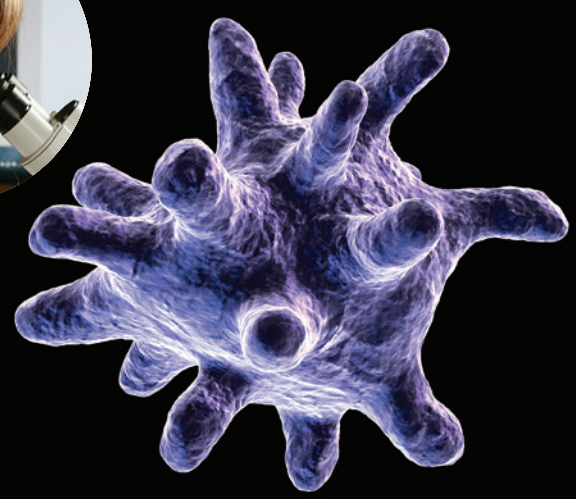
As the team is analyzing cells and studying their responses to polymers in petri dishes in the lab, it is looking for apoptosis, or cell death, to ensure the treatment is effective in killing cancerous cells. The group is also conducting animal trials and collaborating with researchers who have expertise in animals and humans to explain tumors and physiology.

The ultimate dream, while likely many years down the road, is to bring the research to clinical trial. Bratlie says some day it may also be possible to personalize the macrophage response based on cancer stage and other factors, making for a more individualized approach to this combination cancer therapy.

Her research is also applicable in other areas, as macrophages are being studied across Iowa State's campus, including their role in vaccines and parasitic diseases.

"Some diseases, like tuberculosis, actually reside inside the macrophage, so it doesn't get destroyed. Instead it divides and stays. It's a persistent infection," she said. "If we could do something inside the microphage to remove the infection or attack it, that would be a great advancement."





White blood cells called macrophages are considered "first responders" to bodily injuries, removing bacteria and debris.

Brent Shanks, director of the National Science Foundation Engineering Research Center for Biorenewable Chemicals (CBiRC) and Mike and Jean Steffenson Professor of Chemical Engineering

When the National Science Foundation Engineering Research Center for Biorenewable Chemicals (CBiRC) was founded in 2008, its approach of combining biology and chemistry to develop sustainable biobased chemicals was a novel idea.

"At the time, we were trying decide if there was value in having people from the biological area—those who work in enzymes, proteins and microbial systems—in the same center with classical chemical conversion researchers," explained CBiRC's director **Brent Shanks**.

Six years later, it seems the partnership was indeed a good strategy.

CBiRC has more than 25 faculty researchers, numerous graduate students and 35 industry partners focused on changing the chemical industry.

One of the biggest challenges to CBiRC's mission is that there are hundreds of products made from petroleum-based chemicals.

"A lot of organizations working on biorenewable chemicals will focus on one or two products, but it's hard to justify the cost and time it takes to develop such a small number of products when you are dealing with a

SHIFTING THE PARADIGM OF BIORENEWABLE CHEMICALS

CBiRC focuses on platform technologies and new chemicals from biomass feedstocks to replace petrochemicals

market that is so diverse," explained Shanks, who is also Iowa State's Mike and Jean Steffenson Professor of Chemical and Biological Engineering. "We are striving to break away from that lone end-product mindset."

Instead, CBiRC wants to develop a platform technology—one that can be developed and then simply exploited to make a range of different products.

Shanks says novel biological intermediates give CBiRC the opportunity to make this technology a reality.

"We are using biological conversions to get to unique intermediate molecules. From there, we use chemical conversion to go to a range of different chemical products, essentially creating a star diagram, where an intermediate molecule from fermentation can make a whole range of different molecules," he added.

One such intermediate molecule is triacetic acid lactone, which can be created through biological conversion and converted to a variety of products. An example end product created by CBiRC researchers from this platform is pogostone—an antimicrobial that has a great deal of potential but has been difficult to synthesize in the past. By starting with triacetic acid lactone, pogostone was developed in one step.

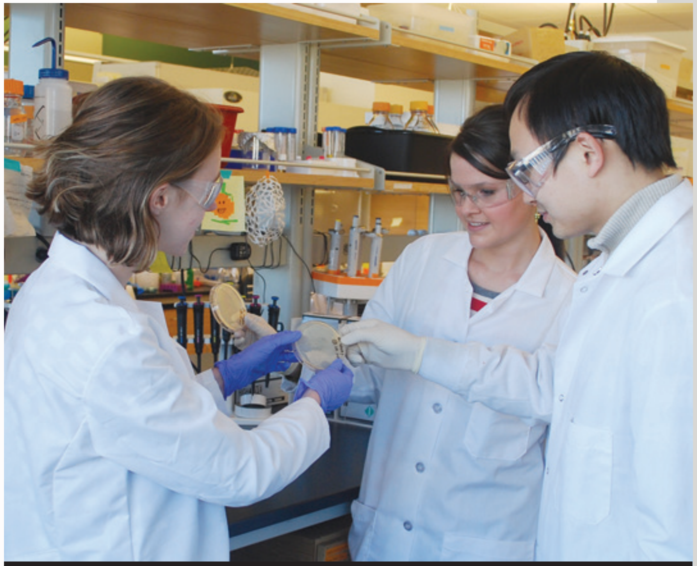
While CBiRC's approach seems subtly different, it's incredibly important. That one intermediate molecule can lead to solutions for high-value, specialty products as well as large-volume, low-value commodity products.

"With our technologies, we can get to families of molecules that people generally haven't ever considered and start to examine the efficacies of these molecules to come up with some interesting options," Shanks said.

As CBiRC researchers publish their work and get patents on technologies, the center is inspiring spin-off companies to help to move the technology forward.

There are currently six start-up companies working on a range of biorenewable chemical products. One example is Glucan Biorenewables, which is exploring how to best make organic furanic compounds such as furfural. And the other companies have similar missions—making a promising product available and accessible.

"There's evidence this platform-technology approach will work, giving the biorenewable chemical industry a foundation for building many products. It's exciting to consider just how much of an impact this could make," Shanks said.



CBiRC researchers develop novel biocatalysts in the interdisciplinary Biorenewables Research Laboratory.

TAKING CYBERINNOVATION TO THE FARM

Data from soil sensors gives researchers and farmers insight into sustainable agricultural practices

Maintaining soil health by protecting land suitable for growing crops continues to be a priority as the world's population rises. Issues like managing the nitrogen cycle, which is also one of the 14 Grand Challenges identified by the National Academy of Engineering, are becoming an increasingly important part of sustainable agriculture.

Ratnesh Kumar, professor of electrical and computer engineering, says being in Iowa gave him fertile ground to expand his domain expertise beyond cyberphysical and embedded control systems (where he has earned recognition as an IEEE Fellow) and apply cyber practices to farming.

Kumar, **Robert Weber**, professor emeritus of electrical and computer engineering, and Ph.D. student **Gunjan Pandey** have developed a portable, wireless, low-cost network analyzer that can be buried beneath crop fields. The sensor measurements are intended to provide a deeper understanding of fertilizer inputs and the nitrogen cycle, both of which are a major source of water quality impairment and also result in greenhouse emissions.

The nitrogen level that has increased from things like fertilizer and certain crops that are produced, like soybeans, ought to be rebalanced, according to Kumar. He adds that plants don't necessarily use all the fertilizer put on them, and that has been causing significant problems such as hypoxia in coastal waters. "With the data from our sensors, we want to be able to determine the adequate amounts of fertilizer to apply as well as uncover ways to improve irrigation practices."

The sensors Kumar and his team have designed collect information about water levels and soil nutrients, gathering details at a wide range of frequencies through measurements of complex impedance. This detail includes capacitance (how an electrical charge is stored) affected by moisture and conductance (how easily an electric current passes) affected by nutrients present in their ionic forms.

A key feature to the sensors is a first-of-its-kind wireless interface. Kumar says such an interface allows the sensors to be used in-situ, so researchers can actively gather information without interfering in any agricultural operations. The design was inspired from "meta-materials" that feature electromagnetic properties not found in natural materials.

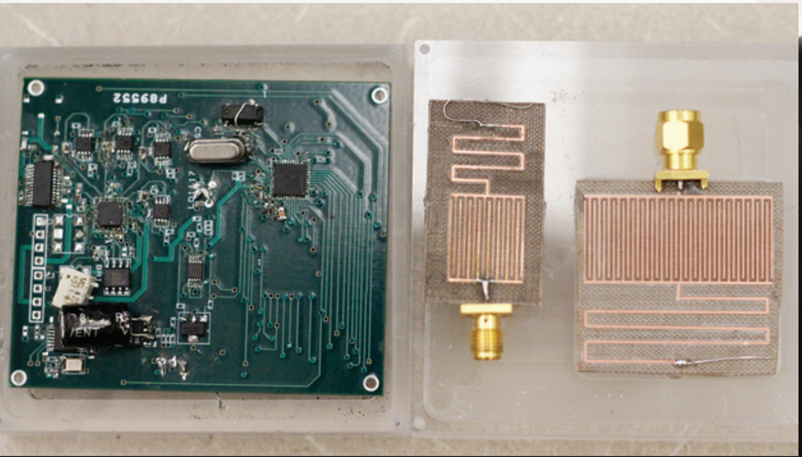
"The sensors also have an inbuilt calibration mechanism so they don't need to be manually calibrated each time conditions, such as temperature, change," he added.

The group is also working with agronomists, specifically soil scientists and crop scientists, to develop sensor-driven models for soil- and crop-growth dynamics. Kumar says such understanding is crucial to the management of soil nitrogen and other nutrients as well as soil health.

His research has been supported by the National Science Foundation through two prior grants and was recently awarded a $1 million,

four-year grant from NSF under the CyberSEES program. Additionally, the sensors component has one pending U.S. Patent.

Kumar says he has even more advancements in his sights. “Going forward, we will be thinking about the entire system of soil, plant and air. They all must be monitored simultaneously to assess the soil, plant and air attributes relevant for soil, water and air health toward sustainable agriculture.”



Electronic microchips send frequencies out in the ground to detect movement amongst other things.

Ratnesh Kumar, professor of electrical and computer engineering

WIND CHARACTERIZATION LEADS TO NEW INNOVATIONS

Expanding wind energy volume takes an interdisciplinary perspective

Aerospace engineering and atmospheric sciences are joining forces and technology at Iowa State to better understand airflow and wind shear on wind farms.

Using computer models, wind and icing tunnel experiments, and field measurements, the researchers say their work can depict individual turbine dynamics, turbine-to-turbine interaction and ultimately how wind farms impact regional wind profiles.

"The projects we're leading give insight into how much wind energy is harvested and also the lifetime of turbines, providing an overall sense of how well a wind farm is operating," said **Hui Hu**, professor of aerospace engineering. "From there, we want to figure out ways to increase efficiency, keeping cost effectiveness a priority."

One way the team is working on improving wind farm productivity involves creating a dual-rotor wind turbine. The project, which was recently funded by the National Science Foundation, features a second rotor that fits into the larger, less aerodynamic section of the main rotor. The smaller rotor is designed to extract energy from wind that initially passes by the main rotor.

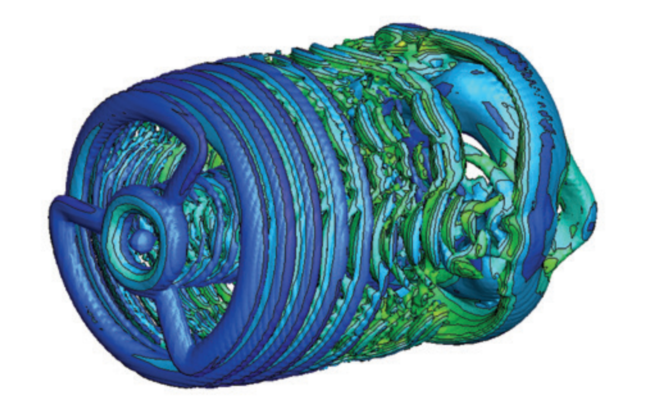
"This setup can also help in mixing out the wake, or disturbances that occur in the atmosphere from the wind turbine, replenishing the energy in the wind before it gets to the next turbine on a farm," explained **Anupam Sharma**, assistant professor of aerospace engineering and Walter W. Wilson Faculty Fellow.

For this project, Hu runs experiments in the wind tunnel while Sharma develops analytical and numerical models. The combination offers a complementary environment where details can be thoroughly investigated, giving the researchers an exact picture of what would happen in the field.

But at Iowa State, the research goes one step further. Bringing in **Gene Takle**, professor of agronomy and geological and atmospheric sciences, the aerospace engineers can confirm their data using on-site measurements to come up with optimal solutions.

Takle's research group has access to power generation data for large wind farms across the state of Iowa. And the group actively measures wind activity on different sites as well. His team looks at several factors, including wind direction, shear and speed, as well as atmospheric stability at different elevations. While his work is primarily investigating how wind turbines affect crops and soil, the information he has can be applied to the research of Hu and Sharma.

Takle says one of the most interesting things the researchers have worked on has been identifying the changes in wind flow as it goes through a large field.



Wake simulation of dual-rotor wind turbine.

"While Anupam has substantiated our observations of changing wind patterns with numerical models, we have yet to determine the implications," Takle said. "For example, as warm, moist air is pushed up, there's potential for it to lead to clouds and eventually rain. We want to know the larger scale impact of this phenomena and if in fact wind farms can influence weather conditions."

As the researchers explore and expand these and other projects—like turbine blade positioning and de-icing, ideal terrain conditions and turbine alignment on farms, turbine noise signatures, and even wind forecasting—they plan to continue collaborating with one another and add insights from others on campus.

"The wind energy field is such that we need input from many disciplines, and the fact that we are able to bring it all together here at Iowa State makes us one of the very few places that can carry out work in such great magnitude," Sharma said. "We're tackling the problem the way it's supposed to be tackled."

Hui Hu, professor of aerospace engineering

Gene Takle, professor of agronomy and geological and atmospheric sciences

Anupam Sharma, assistant professor of aerospace engineering and Walter W. Wilson Faculty Fellow

STRONG ENOUGH TO WITHSTAND EARTHQUAKES

Girder connections are key to bringing accelerated bridge construction to seismic regions

Nationwide, the number of bridge structures considered structurally deficient or functionally obsolete grows each year. The Infrastructure Report Card says that of the more than 600,000 bridges in the United States, one in nine of these bridges is structurally deficient. The challenge, says **Sri Sritharan**, Iowa State University's Wilson Engineering Professor in Civil, Construction and Environmental Engineering, is to reverse this trend while also building bridges that will last longer.

He adds that accelerated bridge construction can be a big part of the solution. The concept gets bridges built and in place a lot faster than current practice, using prefabricated structural components and construction techniques that make impact on traffic minimal. The approach is widely used across the country with the exception of seismic regions.

And Sritharan wants to change that using precast concrete.

He's combining his experience with large-scale testing, analytical simulation and seismic-resistant design, along with his knowledge of precast concrete, to facilitate accelerated bridge construction in areas with seismic activity.

Connections—where the girders meet the cap beam supported by the piers—are essential to a cost-effective, fully integral system.

"The connection has to be designed with constructability in mind, but it must also be sufficiently strong and ductile. We have to make sure the connections remain stronger than the elements connecting to them so we know the connections won't fail and bring down an entire bridge," Sritharan explained.

"Under seismic loading, we're looking to make sure the connections can withstand high-amplitude, low-cycle fatigue loading, so large strains but smaller numbers. Through large-scale testing, our goal is to make sure the connections and the system will respond exactly as we designed."

He also notes specific design features need to be considered for structures in seismic regions, including planning where damage would take place should a strong seismic event occur. Sritharan says controlled damage prevents a structure from collapsing completely and protects people in the area from being injured.

Additionally, having damage occur in visible areas, like the top and bottom of bridge columns, allows for inspectors to swiftly assess any damage to the fullest extent following a seismic event.

Working with the California Department of Transportation, Sritharan and his team looked at several different approaches to designing and accelerating bridge construction for the state. Their work has led to a more cost effective approach, along with several options to connect the girder to the cap.

The findings are also applicable to the overall accelerated bridge construction process, which can make a significant impact in more quickly improving the country's infrastructure.

"As we demonstrated in our experiments, the deck formwork is built off the girders so there isn't any scaffolding underneath. Work can then be completed on top of the structure, making it even less intrusive to traffic using the

Sri Sritharan, Wilson Engineering Professor in Civil, Construction and Environmental Engineering

road underneath. That's a great advantage in heavily populated, urban areas, where girders may be placed overnight," Sritharan said.

In a perfect world, Sritharan envisions precast components for the entire bridge construction process and some special projects have taken advantage of such a concept. "There's a lot of work that needs to be done to improve the quality and lifespan of bridges across this country, and our research focus has been to make that happen more efficiently and cost effectively."

Master's student Robert Peggar examines distress to a bridge deck after simulating a seismic load to a large-scale cap beam-girder-deck test unit.

NEWS B

MECHANICAL ENGINEERING DEPARTMENT TEACHES COURSE IN NICARAGUA

Nine students from Iowa State's mechanical engineering department, as well as Luther College's biology department, relocated to San Isidro, Nicaragua, last June, as part of a sophomore design course.

Students learn about the human-centered design process while working on projects in rural Nicaragua.

The goal of the course was to teach students about the human-centered design process, which involves the consumer or "co-designer" throughout the design. The engineering team then works on the technicality of what the co-designer wants.

Gloria Starns, mechanical engineering senior lecturer, who taught the course with **Mark Mba-Wright,** mechanical engineering assistant professor, came up with the idea for the trip to Nicaragua after brainstorming with two founders of Emerging Opportunities in Sustainability (EOS).

EOS, an organization dedicated to providing under-served communities with access to low-cost appropriate technologies that generate income, improve health and preserve the environment, was founded by mechanical engineering alumni.

The former students reached out to Starns knowing that ME 270 is dedicated to working on projects in developing countries while focusing on the voice of the customer. However, with the class being taught in Ames, students do not have direct contact with the people for whom they are developing products.

With project recommendations from EOS, the course was taught in Nicaragua, giving the students a more meaningful experience. Three student groups created three different products—a rainwater catch system, coffee roaster system and biochar reactor. Before going to Nicaragua, the nine students started their studies with Starns and researched their future projects.

"The opportunity was great, and I would go back in a heartbeat," said **Michelle Bruns**, recent graduate of mechanical engineering.

ITES

BIOLOGICAL SYSTEMS ENGINEERING SENIOR DEVELOPS PROJECT MANAGEMENT SKILLS AND MUCH MORE THROUGH RESEARCH

Bailley Richardson's choice to major in biological systems engineering grew from an interest in using locally produced materials to create valuable products along with her agricultural background. After performing research during her freshman year at Iowa State, Richardson, who is now a senior, knows she's on the right path.

Richardson's research involved biodiesel facilities' techno-economic modeling, algae-based biodiesel, dried distillers grains and aquaculture. She says the experience allowed her to pursue a research and development internship at Feed Energy Company, where she has performed research on animal fats and oils on an industrial scale.

"There was so much I learned outside of my classroom experience while I was researching," Richardson said. "Project management, technical writing, helping others learn—these will all benefit me no matter where I go."

She also stays busy with both Iowa State's and the national branch of the American Society of Agricultural and Biosystems Engineers, and she is the president of ISU BioBus, an interdisciplinary student club that recycles waste vegetable oil from ISU Dining into biodiesel for the CyRide Bus system.

Richardson says she has enjoyed all kinds of activities, but the most valuable was being a peer mentor for freshmen in introductory agricultural and biosystems engineering courses. She plans to continue on to graduate school and pursue a career in research and development.

INDUSTRIAL ENGINEERING STUDENTS IMPROVE PATIENT EXPERIENCES AT MARY GREELEY MEDICAL CENTER

Zach Clarey, **Ian Colpaert** and **Josh Adams**, recent Iowa State industrial engineering alumni, founded the O3 X (www.o3xculture.com) consulting firm three days after graduating. The team initially formed to complete a class project at Mary Greeley Medical Center in Ames, Iowa, to learn more about wait times in the radiology department.

Recent engineering graduates Zach Clarey (left) and Ian Colpaert stand in front of a flow chart used in process improvement projects conducted at Mary Greeley.

After the team gave a presentation to hospital managers and supervisors, the hospital's president and CEO approached the students to suggest another research project, this time focusing on hospital staff responsiveness in the oncology department.

Clarey and Colpaert now work at Mary Greeley as consultants in the hospital's continuous improvement program. Although their career goals initially focused on manufacturing, they now look forward to developing a process that would eliminate the need for a call button except in case of a patient emergency.

(*Adapted from Fall 2014 Mary Greeley Health Connect*)

IOWA STATE UNIVERSITY
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Iowa State's Biorenewables Complex is now complete
Elings Hall and Sukup Hall, two new buildings that serve as the home for Iowa State University's Department of Agricultural and Biosystems Engineering, opened for classes and research in the fall of 2014. The buildings offer a state-of-the-art learning and innovatie environment with more than 100,000 square feet of modern research labs, classrooms, student spaces and offices.
The two facilities—along with the Biorenewables Research Laboratory, which was dedicated in 2010—are part of Iowa State's Biorenewables Complex. The Sukup Atrium connects the three buildings.