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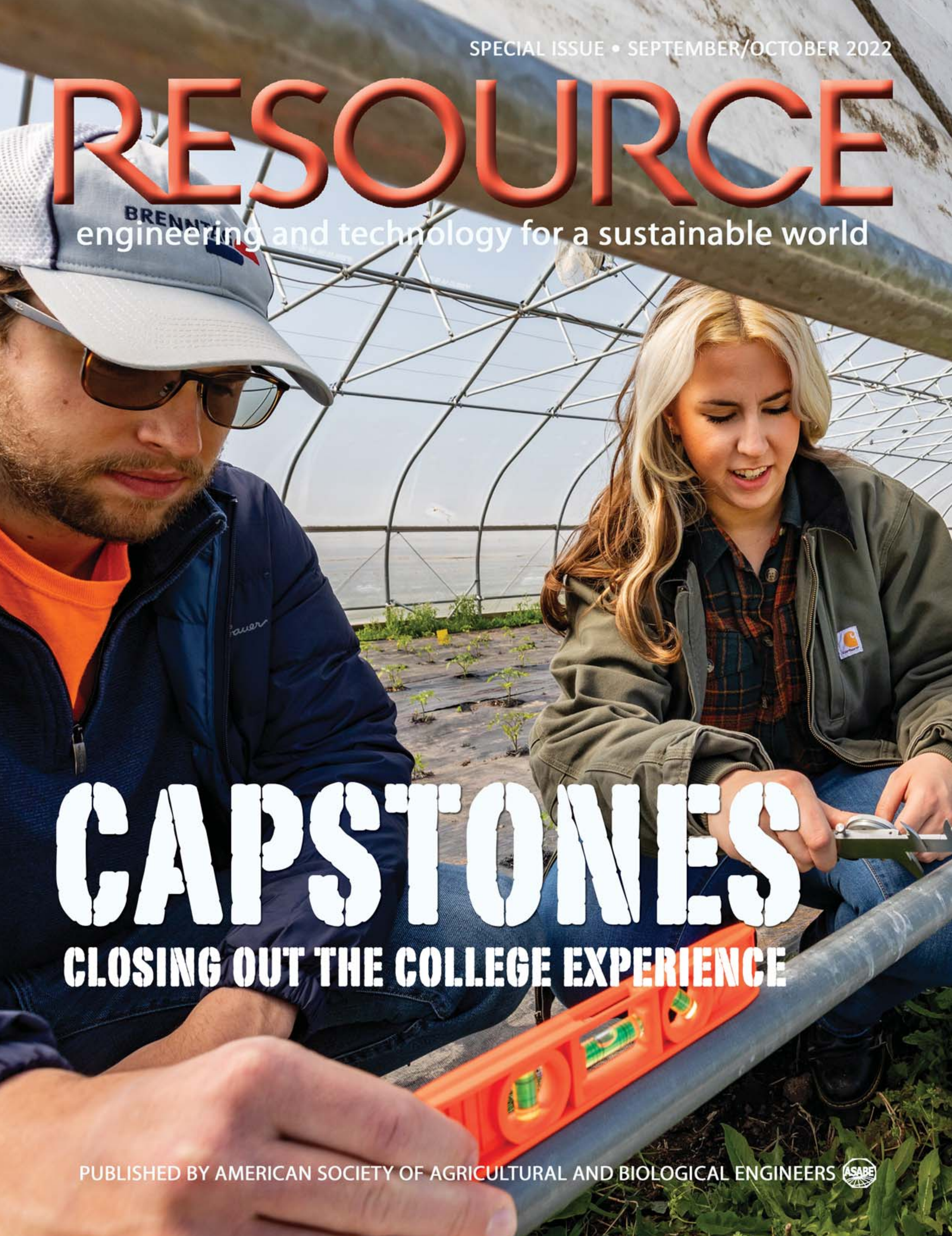
engineering and technology for a sustainable world



CAPSTONES

CLOSING OUT THE COLLEGE EXPERIENCE

PUBLISHED BY AMERICAN SOCIETY OF AGRICULTURAL AND BIOLOGICAL ENGINEERS

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ON THE COVER:
University of Illinois students T.J. Fidler and Daniela Pope work together on their capstone project.

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RESOURCE

engineering and technology for a sustainable world — September/October 2022

CAPSTONES: *CLOSING OUT THE COLLEGE EXPERIENCE*

Guest Editor: **ASABE member Andy Hale,** Professor, Biological and Agricultural Engineering Department, North Carolina State University, Raleigh, USA, Andy.Hale@ncsu.edu.

Most dictionaries define the word capstone in one of three ways: as a stone on top of a wall, as a chockstone at the top of a chimney, or as a crowning achievement. In agricultural and biological engineering education, capstone courses represent the crowning achievement in obtaining a degree. The projects provide a culminating experience where students use their acquired knowledge to design solutions to real-world problems. Their designs are both innovative and exciting. In this special issue, we take a look at the outstanding work currently taking place. Enjoy!

Cultivating Critical Thinking and Problem Solving Skills

Mark Dougherty, P.E., Jonathan Davis, P.E., Oladiran Fasina, P.E., and Jeremiah Davis, P.E.

As up-and-coming engineering practitioners, agricultural and biological engineering students learn the most when they are challenged. In this article, we present some reflections from our senior students.

Senior capstone courses are often chaotic and daunting to students—precisely because designers bring order out of chaos. However, the experience also provides a great sense of satisfaction. Kiara Macdonald, a 2021 biosystems engineering graduate, described what she enjoyed about her design project: "One of my favorite parts was going out and doing the site visits. Visiting the site is a fun way to explore while accomplishing work that can benefit the community."

Olivia Lefevre, a 2021 ecological engineering graduate, expressed the pride she felt in her team's success: "One major accomplishment of our team was winning first place for our design poster. It was great to have our hard work pay off and be recognized. In addition to learning better leadership skills, I improved my technical skills. My skills with modeling software, mainly Civil 3D and Hydraflow Storm Sewers, were greatly improved with this project."

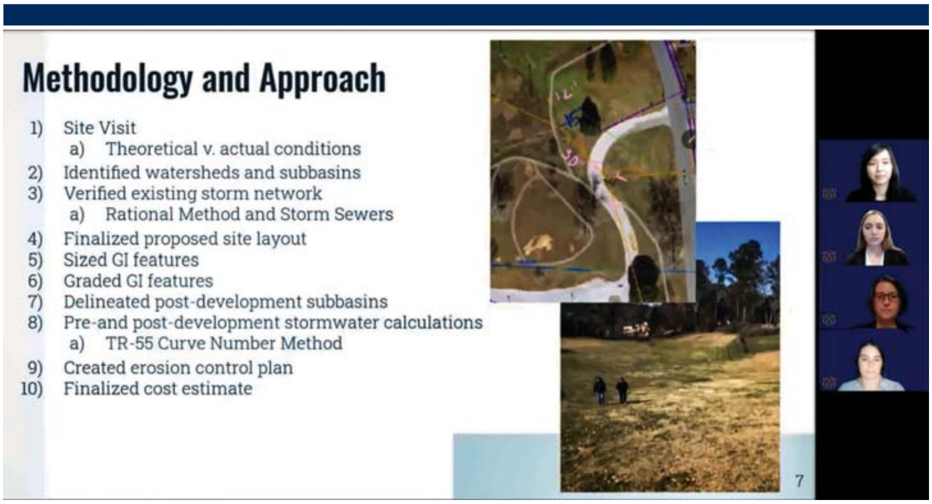
Jay Hruby, one of 60 biosystems engineering seniors in the spring of 2021, wrote that the most important skills she learned were how to think critically and how to solve problems. Jay reflected on her uncertain expectations at the beginning of the senior design class: "Somehow, it was exactly what I expected and nothing like I expected at the same time. No advice about the class can really prepare someone for the experience."

Biosystems engineering students Jay Hruby (*left*) and Courtney Eagle work in the ecological engineering laboratory.

While admitting her frustration with the messy process of engineering design, Jay admitted that the practicalities of the problem helped her rise to the occasion: "The vast number of design constraints was overwhelming, but I quickly realized that it was better to be working with many constraints than with none."

Auburn's biosystems engineering department has been fortunate over the past three years to have gender equity in its student population. Currently, more than half (52%) of our student population is female. As Callie Stuart, a 2021 ecological engineering graduate, wrote: "Being on a team with all women was empowering, and it was one of the few times in engineering that has happened to me." Kiara Macdonald, a teammate of Callie, reported a similar experience: "Working with my team was a great opportunity to promote women in STEM. We were an all-female engineering team, and there was a constant atmosphere of support."

The senior capstone experience at Auburn is not designed to be easy. Rather, it is designed to prepare engineers with practical training through immersion. For graduates like Jay Hruby, who complete their design projects successfully, the result of their labor is enough of a reward. "Of all the courses I completed in biosystems engineering, senior design may have been the most frustrating, but it also best prepared me for the real world."



Students (*top to bottom*) Kiara Macdonald, Cassie Atchley, Callie Stuart, and Kaye Boling present their design improvements for a local park.

ASABE member Mark Dougherty, P.E., Associate Professor, **ASABE member Johnathan Davis, P.E.,** Lecturer and Advisor, **ASABE Fellow Oladiran Fasina, P.E.,** Professor and Head, and **ASABE member Jeremiah Davis, P.E.,** Associate Professor, Department of Biosystems Engineering, Auburn University, Auburn, Alabama, USA, doughmp@auburn.edu.

Creative Ideas from UC Davis Capstone Seniors

Noah Pflueger-Peters

The capstone course at UC Davis gives students in biological systems engineering the skills and experiences they need to become leaders in engineering design. Two exceptional teams are highlighted in this article.

Musical enrichment for horses

One of our student teams developed a device that plays music for horses. Horses respond well to music, and the team's client, Professor Susan Keen in the UC Davis College of Biological Sciences, wanted to give horses more agency.

With advice from Professor and **ASABE Fellow David Slaughter**, the team designed a portable frame, made of PVC pipe, with an ultrasonic sensor. When a horse walks into the frame, it triggers the sensor and one of three pieces of music starts playing. The horses can also switch between the pieces. The team tracked how long each horse listened to each piece to determine which music was most popular.

The team tested the device with five horses. Initially, some horses were afraid of the device or confused by it, but they all got the hang of it. When the team left the area and let the horses use the device freely, the data showed that the horses listened to their preferred music on their own.

This device is the first of its kind, and it will play a role in future research at the UC Davis Equestrian Center. The team wants to continue developing the device to include more effective sensors, and even a feedbag so the horses can eat while they listening to their favorite music.

UC Davis capstone team members (*left to right*) Melanie Siu, Shawn Lupo, Andrew Butler, and Elijah Stockwell pose with their device that lets horses call the tune.

The team takes a liquid sample out of the bioreactor for processing (*photo courtesy Katherine Hung/UC Davis*).

From cheese to plastic

Cheesemaking produces curds—the cheese itself—and whey, which can be processed into whey protein. What's left over is delactosed permeate (DLP), a liquid that contains minerals and some remaining lactose. DLP is often discarded, but a student team developed a bioreactor that processes DLP into polyhydroxyalkanoates (PHA), a highly degradable bioplastic.

The team designed the fermentation system and built and tested the bioreactor. The process starts with hydrolyzing the DLP's lactose into glucose and galactose, which are easier to break down. The hydrolyzed liquid is then added to the bioreactor. As the microbes in the bioreactor consume the liquid, they store energy in the form of PHA.

Samples from the bioreactor are centrifuged to separate the cell mass, and the cells are treated with fresh water, which causes them to release their contents. The cells are then centrifuged a second time to separate the PHA, which can be processed into plastic.

The process uses a waste stream to generate bioplastic, and the waste can be recycled and disposed of in a way that's beneficial to the environment. In the future, the team, advised by Professor and **ASABE Fellow Ruihong Zhang**, plans to maximize the PHA yield and improve the hydrolysis process.

Noah Pflueger-Peters, Content Specialist, College of Engineering, University of California, Davis, USA, napfluegerpeters@ucdavis.edu.

Bridging the Gap Between the Classroom and Industry

Jane Fife, Kristen Conroy, and Kathryn Boening-Ulman

FABE students Emma Jonas, Anna Posta, Faisal Khan, and Shepherd Gruver (*left to right*) present their work on developing a water reclamation system in partnership with Niagara Bottling.

The capstone course sequence at Ohio State University is offered in two program areas: food, agricultural, and biological engineering (FABE) and agricultural systems management (ASM). This course sequence is a culmination of the students' undergraduate experience, allowing them to apply their new knowledge and skills to real-world problems.

The students also learn that there is a lot they don't know, and "failing forward" is a big part of the capstone experience. As student Alyssa Bowles commented, "Failure is part of the design process, and learning what doesn't work can improve your project in the long run."

The 2021-2022 academic year culminated the education of seniors who had endured two years of mostly virtual learning and diminished pre-professional experiences due to the pandemic. In particular, the opportunity to work in teams was missing from many courses during the pandemic.

This unique situation created a need for increased development of the students' communication and presentation skills. The capstone process requires students to work with others outside of their social circle and take the initiative by assigning tasks based on individual interests and abilities. The pandemic highlighted the importance of these capstone elements.

Capstone projects for FABE students reflect the four specializations of their major: food engineering, agricultural engineering, biological engineering, and ecological engineering. Projects led by food engineering students included reducing the use of economic and environmental resources in food processing facilities. Projects in agricultural production included the design of artificial intelligence (AI) image processing for field-based data, electrification of farm equipment, and innovative soil monitoring techniques. Students who focused on biology and ecology designed latrines for rural communities, scale-up of agricultural biologics, solutions for maintaining vernal pools, and various treatment and reuse systems for agricultural runoff.

Students, faculty, and industry partners attend the end-of-year Capstone Showcase.

In addition, through NASA's eXploration Habitat (X-Hab) Challenge, previous teams have worked with NASA engineers on developing solutions for growing plants in space. This year, students focused on NASA's need for transpiration control to reduce energy needs in the food production system. In July, these students competed and placed first in the AGCO Student Design Competition at the 2022 ASABE Annual International Meeting.

The capstone projects developed by ASM students reflected the breadth of agricultural management, with projects extending beyond the technical aspects of agriculture to include holistic management and economic planning. This year's ASM capstone projects included agricultural safety, waste management, drainage systems, and techno-economic feasibility studies of new technologies. Project partnerships were created with industry, academia, and governmental agencies and contractors.

The capstone teams are advised by both faculty and industry partners, which increases the opportunity for professional networking and causes the students to take ownership of their projects. As a result, communication and problem-solving skills are often the students' biggest takeaways from the capstone experience.

Nearly 100 FABE and ASM students participated in the capstone experience in 2021-2022. The highlight at the end of the academic year was the Capstone Showcase, the first such in-person event since the pandemic, where the student teams shared their project results with their peers, sponsors, faculty advisors, and industry partners.

Jane Fife, Lecturer, **Kristen Conroy,** Lecturer, and **Kathryn Boening-Ulman,** Graduate Student, Department of Food, Agricultural, and Biological Engineering, The Ohio State University, Columbus, USA, fife.17@osu.edu.

ABE Students Design Build a CVT as a Capstone Project

Sarah Hays

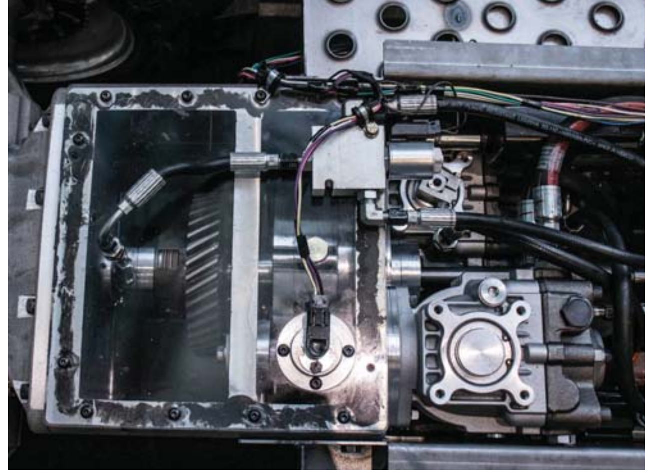
Every year, Iowa State University's Department of Agricultural and Biosystems Engineering showcases the capstone projects created by seniors in the department, who typically present their new ideas to an industry client. This year, **ASABE members Dean Woodwell, Collin Jones, and Colin Kyhl** built their capstone project for the Cyclone Power Pullers, an on-campus club that designs tractors for the ASABE International Quarter-Scale Tractor Competition.

The three seniors are all members of the Cyclone Power Pullers. Every summer, the club participates in the Quarter-Scale Competition, in which student-built tractors are tested for their maneuverability, durability, and ability to pull large loads. All tractors entered in the competition use a standard engine and tires, which the competing teams are not allowed to modify. The rest of the design is up to the teams.

Dean, Collin, and Colin had the perfect plan to complete their capstone project while helping their club. The club members pride themselves on innovation, and they are always improving their tractor design. When the club looked into how they could improve on last year's transmission, the main improvement they wanted was better control, which led to developing a continuously variable transmission (CVT) from scratch.

From designing the CVT with simulation models to testing the physical prototype, Dean, Collin, and Colin spent many hours bringing their project to life. "We designed the transmission in September, and we ordered the parts later in the fall or early winter," Dean said. "After receiving the parts during the winter, we finally tested the prototype in April."

Because of their meticulous calculations, the transmission was fully operational shortly after they began testing the prototype. This was the first time they had used simulation software to model performance before building a device. The simulation model was created in MATLAB Simulink with continuous equations to test the transmission's performance and efficiency.



The CVT installed in the quarter-scale tractor.

Every week, Dean, Collin, and Colin put in long hours—for the two-hour capstone class, for other work outside of class and between classes, and for their capstone project. One of their biggest lessons from the capstone project was how to effectively manage their time. "Between balancing work, class, and our capstone project, it became a significant undertaking, so it was really important to manage our time wisely," Colin said. "Being able to account for a long lead time for parts was also important."

The annual Quarter-Scale Tractor Competition takes place each June, and their capstone presentations were conducted in April, so they successfully designed a working CVT in less than a year. The experience from this project that they will bring to their future careers is huge, said the team's advisor, **ASABE member Stuart Birrell.**

"The real strength of the project is that they did a full project development cycle in just one year," Stuart said. "From design, to simulation, to prototype development and testing. In essence, they worked like a professional design team while learning valuable skills."

Sarah Hays, Communications Specialist, Department of Agricultural and Biosystems Engineering, Iowa State University, Ames, USA, sihays@iastate.edu.

From left to right, ASABE members Collin Jones, Dean Woodwell, and Colin Kyhl work together on the CVT in the lab.

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Improving Water Quality and Reducing Carbon Footprints

Daniel Yoder, P.E.

To find a replacement for sand, which has large ecological and carbon footprints, the team developed a column apparatus to test locally sourced waste materials for use as rain garden media. Team members include (*left to right*) **ASABE members Ella Knight, Bryce Miller, Maddie Ginsberg, and Jaimie Armitage.**

In the University of Tennessee's Department of Biosystems Engineering (BSE), senior design students select their projects from proposals submitted by faculty members and industry partners. We typically have three times as many proposals as teams, so there is always a broad selection. In the first two weeks of the fall semester, the students winnow the proposals, settle on their projects, and build their teams.

In the fall of 2021, the BSE seniors selected a total of four projects, including securing floating wetlands in streams, developing a gas sampler for nitrous oxide emissions from soil, redesigning a bioreactor for growing artificial meat, and developing a testing system for characterizing and selecting rain garden media.

The crux of the rain garden project was that sand is usually used as the primary medium for removal of total suspended solids, nitrogen, and phosphorus. Sand works well, but sand mining often damages the environment. Add in transportation, and sand has large ecological and carbon footprints.

Why not replace the sand in rain gardens with material from a local waste stream? The proposers and mentors for the project, **ASABE member Andrea Ludwig** and Forbes Walker, found no reliable and reproducible technique for evaluating replacement media.

The team's design focused on developing a standardized testing platform and procedure for the selection of local waste streams as replacement media. A successful design would have the ability to evaluate waste streams and account for their source, transportation, and economic and environmental costs.

The resulting design had two components: a column apparatus to test media infiltration and chemical pollutant removal, and a spreadsheet for estimating the cost and carbon footprint. The resulting design was validated with sand and three local waste streams: biochar, spent coffee grounds, and spent beer grains.

The test results showed that biochar competed with sand in terms of contaminant removal, cost, and carbon footprint. Spent coffee grounds and beer grains had low costs and small carbon footprints, but they added nitrogen and phosphate, rather than removing them from the effluent. In sum, the tests showed that the designed system was useful for comparing local waste streams as sand replacements.

Team members and **ASABE members Jaimie Armitage and Maddie Ginsberg** are now BSE graduate students, and they just helped direct a 4-H training activity.

With this kind of experience, University of Tennessee's BSE graduates have 100% placement in industry. In addition, in 10 of the past 13 years, our BSE design teams have placed first, second, or third in ASABE-sponsored student design competitions. This legacy prepares our students for success as they tackle real-world problems wherever their careers take them.

As one recent grad put it, "BSE senior design allowed us to spend a full academic year on a single project. Working in small teams for that long allowed us to develop significant understanding and hands-on skills related to our major and our career goals. We prototyped, built, and tested our design in the environment required by our project goals, and we received frequent feedback that helped turn our ideas into viable designs."

ASABE member Daniel Yoder, P.E., Professor, Department of Biosystems Engineering and Soil Science, University of Tennessee, Knoxville, USA, dyoder@utk.edu.


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Solving an *n*-Dimensional Challenge (where *n* varies between 4 and ∞)

John Lumkes, P.E.

Students present their capstone project to external reviewers during the end-of-year Capstone Event (*photo courtesy of Tom Campbell, Purdue University*).

Q: How do you know if a capstone instructor is an optimist or a pessimist?

A: Ask them to describe their capstone experience.

Their experience might sound something like this:

> *"Our capstone students partner with industry, organizations, and individuals to solve real-world problems by applying all their previous coursework, resulting in incredible local and global impact. And they do this while taking other courses, preparing for life after graduation, looking for employment or applying to graduate school, studying for the Fundamentals of Engineering exam, volunteering in the community, and finding time to enjoy the extracurricular activities that passed them by during the first three years."*

Students work on their projects in the student capstone project work space (*photo courtesy of Tom Campbell, Purdue University*).

Or perhaps it sounds something like this:

> *"Our capstone students are assigned projects that they become unhappy with because their team members don't do any work; or their sponsor is hard to reach and expects them to know things they haven't learned in class; or the team figured out the ideal solution in the first week, yet they are forced to research the problem and look for other solutions; or their solution is technically perfect and meets all "specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors" (ABET Student Outcome 2), but their project is so unique that there are no applicable codes or standards."*

Humor aside, if you have taught capstone courses long enough, then you have had years when you might give the first answer, and years when you might give the second answer (and be able to continue the list well beyond the above examples). In fact, these two answers are not mutually exclusive. Instead, by working through some of the experiences described in the second answer, students often end up enjoying aspects of the first answer in their capstone experience.

There are many layers to capstone, especially when ABET accreditation relies heavily on the capstone program. The capstone experience is like an iceberg—only a small part is visible, and most of it hidden, supporting the part that is visible. This foundational support is typically provided by the department, the university, alumni, industry, and friends, enabling the students to be the visible tip of the capstone iceberg.

For an instructor, this layered complexity also makes capstone one of the most fun, and most frustrating, classes to teach. Fun because, while the course design remains essentially the same from year to year, each teaching experience is different (different projects, new sponsors, unexpected successes, unforeseen challenges, etc.). Challenging because compared to a traditional class, there are multiple dimensions to capstone that are sometimes beyond our control as instructors.

Projects that involve real problems, external stakeholders, multiple solution paths, various space and budget requirements, and so on, mean that we often have to make quick adjustments on short notice to optimize student learning, meet stakeholder requirements, collect necessary assessment data, and provide a net benefit to the end users of capstone projects (following the "do no harm" principle).

My apologies if you expected details about the capstone experience at Purdue! Somehow my introduction to the topic became the entire article. Let me conclude with an answer to the question implied in the title: what are the four must-have dimensions for any capstone course? Eager students, engaged instructors, challenging projects, and thorough assessment. Feel free to add more dimensions, based on your own experience as a capstone instructor.

ASABE member John Lumkes, P.E., Associate Professor, Department of Agricultural and Biological Engineering, Purdue University, West Lafayette, Indiana, USA, lumkes@purdue.edu.

Illinois Capstone Students Are Considered Working Engineers

Ann-Perry Witmer, P.E.

Capstone Associates Inc., a simulated engineering consulting firm in the Department of Agricultural and Biological Engineering (ABE) at the University of Illinois, gives graduating seniors a realistic glimpse of their future careers.

Drawing on the instructor's experience as a professional engineer, the ABE capstone course requires the students to work with clients, specify their project scope and budget, manage schedules and billing, and produce deliverables that meet performance metrics.

At Capstone Associates, the students are converted into project engineers during the second week of class, after which they attend continuing-education lectures in one class each week and participate in stand-up status reports in the second class. The status reports allow the teams to share their successes and setbacks so that they can learn from each other and commiserate about the problems they encounter.

The instructor and teaching assistants fill the roles of principal and business managers at the engineering firm, while other ABE faculty act as subject-matter experts whom the teams can consult, presuming that they have adequately budgeted for the experts' time.

The client may be a local agricultural organization accustomed to working with students, but the clients can range from Fortune 100 companies to international non-profit organizations.

"At first, it was difficult to adjust to the Capstone Associates structure," said 2022 capstone student Daniela Pope, who worked with a team that designed a deep-tunnel structure for the Student Sustainability Farm. "We weren't lectured, like in a traditional engineering course. Instead, the teams were invited to collaborate with one another, like in an engineering firm."

Daniela's teammate T. J. Fidler agreed: "Making a direct impact on a client, in real time, was an amazing experience. I was able to better understand all of the details that define a project of this nature. And the experience of working with a real client gave me an opportunity to expand my soft skills."

At the start of the course, the students apply to specific projects but are assigned to teams by the instructor based on their expertise as well as the personal strengths they bring to the group. This assignment process, along with the required weekly timesheets and status reports, surprises some students who expect to define their own project and pick their own teammates. However, the business-like structure quickly becomes a positive aspect of the experience.

University of Illinois ABE students (*left to right*) T. J. Fidler and Daniela Pope take a break from their project to pose for a photo.

"Our students are exquisitely prepared to undertake engineering projects because this course provides them with a realistic understanding of what it's like to work as a team and address client needs," said ABE department head and **ASABE Fellow Ronaldo Maghirang.**

There's much more to engineering than technical proficiency. After completing their undergrad studies, students' first experience as working engineers is often a shock. With Capstone Associates, we lessen that shock by gently exposing our students to the realities of workplace expectations and challenging clients.

Ann-Perry Witmer, P.E., Senior Research Scientist, Applied Research Institute, University of Illinois, Urbana-Champaign, USA, awitmer@illinois.edu.

Capstone Design Supports Research at Kansas State

Ed Brokesh, P.E.

In the Department of Biological and Agricultural Engineering, senior design projects start in the spring semester of junior year, when students enroll in a pre-senior design course to explore project ideas. Design teams are formed from the ideas generated in this course.

In mid-August, the students receive an email detailing the project they will be working on and the team members they will be working with. A faculty advisor is provided for each project, but it's up to the students to meet with the advisor. This is the students' project, and the students are expected to take the lead.

A great senior design project starts with a unique challenge and an abundance of enthusiasm. Professor Kristin Michel of Kansas State's Department of Biology has provided several such projects to the senior design class. Recently, Professor Michel needed a way to create 1 μL wells in bacteria-infused agar plates for a series of tests that her lab was running on mosquito hemolymph (hemolymph is a fluid that circulates in arthropods, similar to blood in vertebrates). The manual method used to create these microliter wells consumed a considerable amount of time and produced many unusable wells. Further, the shape of the wells is critical to the success of the experiments. A defect in a well can render a test unusable, wasting time and materials.

Cross section view of observed well failures versus desired well shape.

The students assigned to this project initially expected this to be a simple project with a simple solution. After all, how hard could it be to create eight holes? As many a seasoned engineer will tell you, seemingly simple projects are often the most difficult.

As the students dived into the details of the project, including the size of the components, the properties and proper care of the agar substrate, and the need for laboratory-grade sterilization, they realized that this would be an especially challenging project.

The team's initial designs created unusable wells, required equipment that was too complex and costly, or resulted in a device that could not be cleaned after use. After numerous failures, the team members met with their advisor, who encouraged them to study the properties of agar and the processes used for conducting the experiments. That in-depth study yielded a great solution.

"The students assigned to this project initially expected this to be a simple project with a simple solution. After all, how hard could it be to create eight holes? As many a seasoned engineer will tell you, seemingly simple projects are often the most difficult."

The team's final design was a combination of a device and a procedure. The device is a 3D printed stencil that is placed over a petri dish as the agar solidifies. Metal pins installed in the stencil create the microliter wells in the agar. Perfectly shaped wells can be created by timing when the stencil is placed on the agar and then removed.

Example of a petri dish with improperly shaped wells. Note the lifted auger in center of the picture.

Prototype of final stencil design.

The device and process that the team developed were very different from what the lab personnel had used previously. As a result, an unexpected requirement of the project was training the lab personnel on how to use the new device. Ultimately, the improved accuracy of the microliter wells will improve the quality of the research performed in Professor Michel's lab.

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Senior Design Students Tackle Neonicotinoid Contamination

Emily Case

In the Department of Biological Systems Engineering at the University of Nebraska-Lincoln, the 2022 senior design projects addressed a wide range of topics. One team stood out by taking on a topic in largely uncharted territory—remediation of neonicotinoid contamination in water.

The student team partnered with the Eastern Nebraska Research, Extension, and Education Center (ENREC) in Ithaca, Nebraska. Team members included Dawson Bartunek, Taya Derun, **ASABE member Helen Little**, Scott Smith, and Jordan Talmon.

The challenge

Neonicotinoids are neurotoxins used as pesticides. In concentrated amounts, they pose a risk to wildlife, especially insects and aquatic species, and at certain levels they can be toxic to humans. No common practices are available to treat water contaminated with neonicotinoids.

The AltEn ethanol plant, which opened in 2015, received 98% of all discarded treated seed in the U.S., an estimated 300 to 450 tons daily. The two waste products from ethanol production were liquid wastewater and solid distiller's grain, called wetcake.

In February 2021, the Nebraska Department of Environment and Energy (NDEE) issued an emergency order directing AltEn to cease discharge of wastewater into its lagoons. In response, the facility ceased operations.

A few days later, a four million gallon digester containing liquid manure and contaminated wastewater burst on the site, sending its contents down a nearby stream. The next month, the State of Nebraska sued AltEn for violations against the U.S. Environmental Protection Agency and NDEE.

In June 2021, a coalition of six seed companies volunteered to remediate the wastewater lagoons and wetcake. This coalition is known as the AltEn Facility Response Group (AFRG). The first phase of AFRG's remediation plan involved managing the lagoons' wastewater levels, transferring untreated wastewater out of the digesters, and consolidating the wetcake and sludge materials.

AFRG is now in the next phase of the plan, which involves treating the wastewater in the lagoons, building a new emergency pond, irrigating cropland with treated wastewater, and covering the wetcake pile to prevent stormwater runoff.

The solution

The student team needed to reduce the concentrations of neonicotinoids to below the acute toxicity levels for aquatic invertebrates. The team decided on a three-stage treatment process involving UV treatment, retention ponds, and a constructed wetland.

The first stage is a groundwater pump-and-treat system. The UV treatment building, located downstream from the AltEn plant, will intercept the groundwater plume of neonicotinoid contamination. Placing the UV system first in the treatment process provides an initial shock to quickly reduce the neonicotinoids in the incoming water.

This aerial photo, taken on September 9, 2021, shows the south side of the controversial AltEn ethanol plant in Mead, Nebraska (*photo courtesy of Nebraska Department of Environment and Energy*).

The second stage is two retention ponds that will hold water so that the final treatment stage does not get flooded. The retention ponds will also serve as an auxiliary method for breaking down neonicotinoids in the surface runoff.

The final stage is a constructed wetland with two independent cells. The constructed wetland will anaerobically degrade neonicotinoids by removing chlorine from the chemical structure, followed by aerobic degradation to produce nontoxic byproducts.

The team members said their plan uses research from a variety of labs that have studied neonicotinoids. "This strategy will be a first step in developing effective methods to remediate these harmful chemicals," they said in their final report.

Emily Case, Communications Specialist, Department of Biological Systems Engineering, University of Nebraska, Lincoln, USA, ecase3@unl.edu.

UNIVERSITY OF NEBRASKA

CAL POLY, SAN LUIS OBISPO

Cal Poly Seniors Design and Build Tractor-Mounted Cranes

Aidan Fischer and Matt Haberland

Each year, fourth-year students in the Department of BioResource and Agricultural Engineering (BRAE) at Cal Poly, San Luis Obispo, California, engage in a year-long capstone project.

In the fall, we learn how to design and build the mechanical components of agricultural machinery, including hydraulic circuits and steel structures. We also learn to elicit needs statements from a client, incorporate knowledge from a literature review to transform those needs into engineering specifications, brainstorm design concepts, and choose the best design from the various alternatives.

In the winter, we learn how to incorporate moving elements into our designs, such as ball bearings, gears, clutches, and brakes. In the lab, we iteratively refine our CAD models from the previous fall, meeting with faculty weekly to demonstrate our progress and get feedback. When our designs are complete, we fabricate our machines in the BRAE labs.

In the spring, we test our devices; we reflect on our successes, our shortcomings, and how we can improve; and we document our work by preparing a summary video, a product manual, and a technical report for the client.

During the 2021-2022 academic year, all BRAE teams worked with the same client, the Cal Poly BRAE department, to create a tractor-mounted crane. Each team was told only that the crane must meet three criteria:

- Mount to the three-point hitch of a tractor.
- Be powered by the remote hydraulics of the tractor.
- Cost no more than $1,750 to build.

After interviews with experts in agricultural equipment design, several meetings with faculty to refine our designs, and many hours of work turning paper drawings into 500-pound machines, all six teams produced cranes that could lift a one-ton load about ten feet into the air. We competed in a rigorous series of tests—each team designed one of the tests—to determine which crane could lift the heaviest load, which was most user-friendly, and other factors.

We applied almost every topic discussed in the classroom to our cranes. This tight coordination between lecture and lab inspired us to value the link between classroom learning and practical application. Without this coordination between theory and practice, our cranes would certainly have failed the tests designed by our peers!

This senior project experience exemplifies Cal Poly's core philosophy: "Learn by Doing"—which we students take to heart. As senior BRAEs, we designed our projects based on the actual needs of clients who would benefit from our solutions. These same clients rated the performance of our final projects to judge whether we met their needs.

Despite frustrations, repeated failures, and fatigue, our work paid off, and what began as a chicken-scratch drawing on a whiteboard in the low-light student lounge is now a versatile and useful tool. With this experience, we are one step closer to our common goal: making a positive impact in our communities and the world around us.

"what began as a chicken-scratch drawing on a whiteboard in the low-light student lounge is now a versatile and useful tool."

Cal Poly seniors (*left to right*) Tyler Tsuji, Brant Baugher, Cason Roberts, Aidan Fischer, and Garon Gostanian pose with their successful prototype of a tractor-mounted crane.

Aidan Fischer, undergraduate student, and **ASABE member Matt Haberland,** Assistant Professor, Department of BioResource and Agricultural Engineering, Cal Poly, San Luis Obispo, California, USA, mhaberla@calpoly.edu

Capstone at Virginia Tech: Putting It All Together

Cameron Warren, Cully Hession, P.E., and Dwayne Edwards, P.E.

Culpeper County BMP and Stormwater Infrastructure team members (*left to right*) ASABE members Amara Shareef and Kelly Ruffner, and Chloe Wynns.

"Do what you love. Create a better world." That's the challenge we present to students who enter Virginia Tech's Biological Systems Engineering (BSE) program as sophomores. Over the next three years, BSE students explore their interests and hone their engineering skills, culminating in the senior capstone course.

Each year, a new set of projects is nominated by BSE faculty, graduates, and other contributors. The descriptions of these projects are very broad to encourage creativity, and the students select from a wide range of topics. For example, the fall 2021 choices included creating high-protein nutrition bars, isolating protein from microalgae residue, and developing design plans for a stream restoration project.

In 2022, nine student teams solved practical problems. Based on the results of the end-of-semester poster competition, the following three teams ranked highest in creativity, clarity, organization, approach, process, and results.

Hellbender Project in Tom's Creek

The eastern hellbender, a giant salamander, is an important indicator of stream ecosystem health in the eastern U.S. and has recently been identified in the Tom's Creek watershed in Virginia. A section of Tom's Creek is experiencing bank erosion, over-widened channels, and riparian buffer loss, all of which decrease the hellbender habitat. This team redesigned two stream crossings in the affected area to limit bank erosion and downstream sedimentation and included hellbender habitat structures.

Team members for the Hellbender Project in Tom's Creek (*left to right*) Nathaniel Abrahams, ASABE members Rachel Lake and Sarah Loomis, and Jacob Bellinger (team member Diana Schmidt not shown).

Culpeper County BMP and Stormwater Infrastructure

Due to population growth, waterways in Culpeper County, Virginia, have suffered water quality impairments and created concerns about local flooding. Flooding can affect public welfare, and it can be managed through infrastructure. This team worked with Friends of the Rappahannock, a local environmental organization, to develop viable and cost-effective green infrastructure and best management practices (BMPs) to support the region's watershed implementation plan.

MOPP System for Heart Transplantation

Heart disease is one of the leading causes of death in the U.S., and heart transplantation is sometimes the best treatment option. Preservation of the donor organ is critical, but a limitation of current preservation techniques is their inability to retain organ viability, which can result in tissue damage. This student team designed a Machine Organ Perfusion Preservation (MOPP) system for heart transplantation that sustains the donor organ during transport and delivery.

At Virginia Tech, the BSE capstone course requires a commitment. It is resource-intensive, high levels of instructor coordination and oversight are required, and no two years are the same. However, the commitment is more than repaid by the benefits—not just for the students, but also for the mentoring teams and instructors.

As long-time BSE capstone instructor Cully Hession said: "Watching students apply what they've learned in the classroom to what they're passionate about is why I love teaching this course."

Cameron Warren, Communications Specialist, **ASABE member Cully Hession, P.E.,** Professor and Graduate Program Director, and **ASABE member Dwayne Edwards, P.E.,** Professor and Head, Department of Biological Systems Engineering, Virginia Tech, Blacksburg, USA, dredwards@vt.edu.

The Machine Organ Perfusion Preservation (MOPP) system developed by BSE students at Virginia Tech.

Joining the Fight against an Invasive Species

Dana Kirk, P.E., Luke Reese, Ilce Medina-Meza, Matt Symbal, and Nicholas Johnson

The project team at the USGS Hammond Bay Biological Station (*left to right*): Jacob Soullier, Ryan Snyder, Madalyn Allen, and Catherine Christenson (*photo by Nick Johnson*).

Each year, seniors in the Department of Biosystems and Agricultural Engineering at Michigan State University participate in capstone design projects. This year, one of our teams worked with the U.S. Fish and Wildlife Service (USFWS) and the U.S. Geological Survey (USGS) to address the control of sea lampreys, a notorious invasive species in the Great Lakes and surrounding tributaries.

The sea lamprey invasion has severely affected the Great Lakes ecosystem and the native fish populations. Lamprey control is needed to protect the fishery industry, which is valued at over seven billion dollars annually. The traditional control methods involve preventing adult lampreys from reaching their spawning habitat and treating streams where lamprey larvae occur with selective pesticides.

A supplement to these traditional methods is the release of sterilized adult males. Because sea lampreys do not feed while mating and die after mating, the release of sterile males that mate with females is a triple whammy—the males die, the females die, and there are no offspring.

Males are sterilized using a complex machine that injects a chemosterilant, but the current auto-injector design is more than 20 years old and prone to malfunction. Therefore, the goal of this capstone project was to design an effective sterilization method that minimizes the hazards to personnel, increases the speed with which lampreys can be sterilized, and minimizes lamprey mortality during processing.

Several design alternatives were included in the team's project report. The five criteria were human safety, lamprey mortality, effectiveness of sterilization, commercial readiness, and cost. The design that was selected for further development was was immersion in Bisazir, an anaziridine compound used in the current injection method for sterilization of sea lampreys.

The selected design could more than double the number of lampreys that are sterilized during the four-week season. The efficiency of the design will keep operating costs low, and the overall cost will mostly be influenced by the cost of formulating Bisazir in the lab because the formulation is specific to lamprey sterilization.

The project team collaborated with the USGS to use materials that were already owned by USGS facilities to reduce the cost. A layout for the sterilization process, which would fit within a facility already owned by the USGS, was designed in AutoCAD.

The overall cost reduction will be up to $300,000 when compared to the current method of auto-injection. There is also potential for automation of the process, which would further improve the efficiency and reduce human exposure to Bisazir. Most of all, this new method for lamprey sterilization will help protect the ecology and economic value of the Great Lakes.

An injury inflicted by a sea lamprey (*photo by Marc Gaden, Great Lakes Fisheries Commission*).

ASABE member Dana Kirk, P.E., Associate Professor, **ASABE member Luke Reese,** Associate Professor, and **Ilce Medina-Meza,** Assistant Professor and Faculty Advisor, Department of Biosystems and Agricultural Engineering, Michigan State University, East Lansing, USA; **Matt Symbal,** Supervisory Fish Biologist, U.S. Fish and Wildlife Service, Marquette, Michigan, USA; and **Nicholas Johnson,** Research Ecologist, U.S. Geological Survey, Hammond Bay Biological Station, Millersburg, Michigan, USA.

UNIVERSITÉ LAVAL

Christmas Tree Cultivation: A Successful Capstone Project

Mohamed Khelifi, P. Eng.

Université Laval's agri-environmental engineering program includes two courses that students take in the fall and winter semesters of their final year to complete a capstone design project. The emphasis is on the acquisition of knowledge in an autonomous way through the activities performed by the design teams.

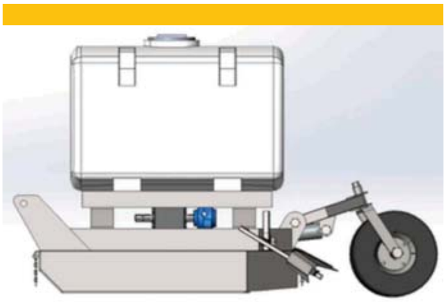
At the beginning of the fall semester, teams of two or three students are formed based on their shared interests. The teams focus on defining the scope of their project based on the needs, constraints, and criteria identified by the client. They generate several potential solutions and select the most appropriate solution in cooperation with the client.

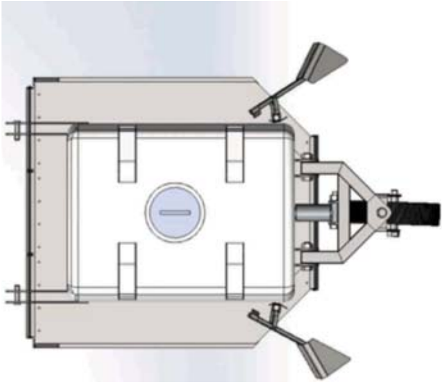
At the end of the fall semester, they present a written report and make an oral presentation to faculty members, professional engineers, students, and clients. Based on the feedback they receive, the teams start the second course with new ideas for their project. At the end of the winter semester, they present their achievement in a final written report and an oral presentation.

A great example of a capstone design project was suggested by Dominique Choquette, an agronomist in Quebec's Ministry of Agriculture, Fisheries, and Food. It concerned the design of equipment that could combine mowing and spraying in Christmas tree cultivation. The idea originated with the mechanization committee of the Quebec Christmas Tree Growers Association (QCTGA), which wanted a solution to the lack of manpower in this sector.

The project team consisted of two students: William Falcon and Étienne Marineau-Bélanger. They met with two growers as well as members of the QCTGA to identify the problem, analyze the needs and constraints, and learn more about Christmas tree cultivation. William and Étienne generated several solution concepts, and the most promising concepts were selected considering the interests of the growers.

> We were able to solve a real problem, in a school context, with Professor Khelifi and industry professionals guiding us at each stage. There is no better way to prepare for a career in engineering!





CAD drawings of the combined mower and sprayer for use in Christmas tree cultivation.

The selected concepts were modeled in SolidWorks and presented to the QCTGA committee to select the most appropriate concept. William and Étienne then performed the final modeling, taking care to select the appropriate materials, dimension the generic parts, and design the custom parts. For safety reasons, theoretical and finite element analyses of various critical points were included in the modeling.

At the end of the winter semester, William and Étienne gave an oral presentation and submitted a final written report, as well as the deliverables needed to implement the design. The deliverables included a detailed assembly document, a parts list with costs and suppliers, drawing files for manufacturing the custom parts, drawing files for all parts and assemblies used in the design, and diagrams of the hydraulic and spraying systems.

"We loved accomplishing this project and overcoming the challenges," William said. "We were able to solve a real problem, in a school context, with Professor Khelifi and industry professionals guiding us at each stage. There is no better way to prepare for a career in engineering!"

Étienne added, "The biggest challenge was to understand the needs of the customers, since the production of Christmas trees was new to us. However, working on a new subject really broadened our horizons. We hope that our project will be useful for Quebec Christmas tree growers and other similar producers."

ASABE member Mohamed Khelifi, P. Eng., Professor, Department of Soils and Agri-Food Engineering, Université Laval, Québec, Canada, Mohamed.Khelifi@fsaa.ulaval.ca.

Inclusive Engineering Design

Fischer Robinson, Libby Haydel, and Marybeth Lima

For most children with visual impairments, scoping out a new playground requires having a parent or teacher lead them around while they memorize where the equipment is. This process cuts into playtime, and it can lessen a child's independence.

To address this issue, students in the Department of Biological and Agricultural Engineering (BAE) at Louisiana State University collaborated with the Louisiana School for the Visually Impaired (LSVI) in Baton Rouge. Working together, they designed and built a multi-sensory map that creates a safer and more inclusive play experience for the children at LSVI.

The project began when former Biological Engineering student Brandon Tramontana had an epiphany while working for the LSU Community Playground Project, an engineering civic engagement program housed within BAE. Although playgrounds are designed to be accessible, few are tailored to the needs of children who are blind or visually impaired.

Brandon received an LSU Discover Undergraduate Research Grant to investigate the nature of play for children who are blind or visually impaired. He interviewed students, staff, and parents at LSVI and the McMains Children's Developmental Center, focusing on the children's approach to play, their challenges during play, their interactions with others, and ideas for better play. Based on those interviews,

View of the tactile map and the playground that it represents. The cutout at the bottom of the stand was requested by LSVI as a place to store a step stool, which is a "focus area" skill for students who are visually impaired or blind.

Brandon got the idea for a tactile model of the LSVI playground that children could explore by touch.

A team of senior capstone students, including Kenzie Dupont, Gracie Kennard, Tiffany Le, Cameron Matherne, Fischer Robinson, and Thomas Tran, worked with BAE professor and **ASABE member Marybeth Lima**, and LSVI staff Stacy Cox, LaRonda Doakes, Blanche Faulk, Jennifer Gaudet, and Anna Gayle, to develop Brandon's idea into a design.

The students got first-hand experience in navigating the playground without sight by wearing special-purpose goggles that simulated different levels of visual impairment. "As I moved throughout the playground," Fischer said, "I began to understand the importance of textures. I could tell where I was in based on the way the cane felt as it glided along the ground. This idea played an important part in the design of the tactile map."

Children with visual impairments can distinguish between contrasting colors. Therefore, the tactile map uses specific color-texture combinations to indicate different components: circular indentations in yellow represent platforms, raised bumps in black represent the gravel protective surface surrounding the play equipment, and smooth red surfaces represent the slides.

The senior design team worked with LSVI to co-develop and test several prototypes with the children using the playground (with IRB approval), and comply with design standards, especially from the U.S. Access Board, to finalize the design. A second senior design team (Abdullah Alturaifi, Jamekia Colbert, Eva Gatune, Isabelle Maxwell, and Shane Vallery) helped the first team to install the map and subsequently worked with LSVI staff to collect data on its functional performance to ensure that the map is effectively serving the children who attend LSVI.

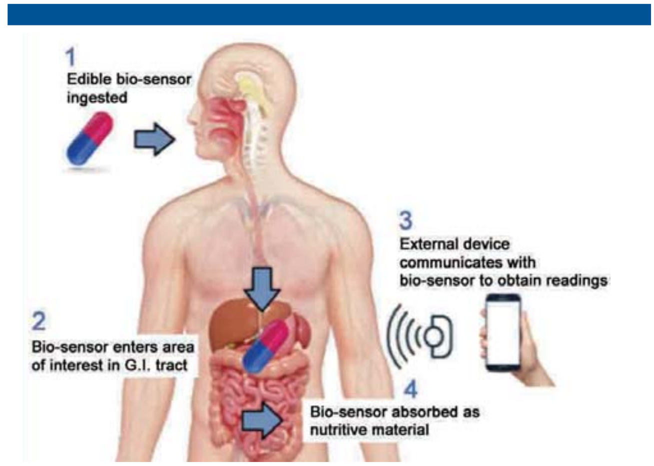
When asked about the tactile map, Blanche Faulk, the O&M and Outreach Coordinator at LSVI said, "The BAE students were wonderful to work with, and they asked amazing questions. They went all out to understand the project. Our children love the tactile map, and they love teaching new children about it."

Thomas Tran assisting Kenzie Dupont while she moves across multiple textures toward the playground. Sudden changes in ground surface or texture can be dangerous for children who cannot see them and were a focal point of the tactile map.

Fischer Robinson, Student, Department of Biological and Agricultural Engineering, **Libby Haydel,** Communication Manager, College of Engineering, **ASABE member Marybeth Lima, P.E.,** Professor and Chair, Department of Biological and Agricultural Engineering, Louisiana State University, Baton Rouge, USA, f.robinson930@gmail.com,

LOUISIANA STATE UNIVERSITY

Antenna transmission test with function generator and pocket oscilloscope.



The proposed edible sensor platform for non-invasive biosensing.

Bioengineering an Edible Antenna for Ingestible Sensors

Veronica Tami and Spencer Serrano

Bio-compatible electronics have shown enormous potential for various biological engineering applications, including packaging, food safety, and human health. Minimally invasive electronics, such as bio-based devices, are needed in healthcare because standard devices can induce allergic reactions or infections. In the packaging industry, edible electronics may reduce the cost and labor associated with food product monitoring.

Under the direction of our mentor, **ASABE member Ziynet Boz**, we set out to design electronic components for an ingestible biosensor platform. After researching ingestible biosensors, we decided that the power and communication functions were the most crucial elements of these devices. Therefore, we created two teams—one team to develop a biomimetic edible fuel cell, and the other to fabricate a working patch antenna. Both components are composed of edible materials and follow daily allowances established by the federal government.

Our team's focus was the patch antenna. The design for the patch antenna was inspired by the near-field antennas used in RFID scanners and cell phones. We chose to study near-field antennas because their simplicity made it easy to approximate conventional electronic materials with food-grade products. We envisioned that our antenna would transmit and receive data and could be readily incorporated into an internet-of-things platform for gastrointestinal sensing.

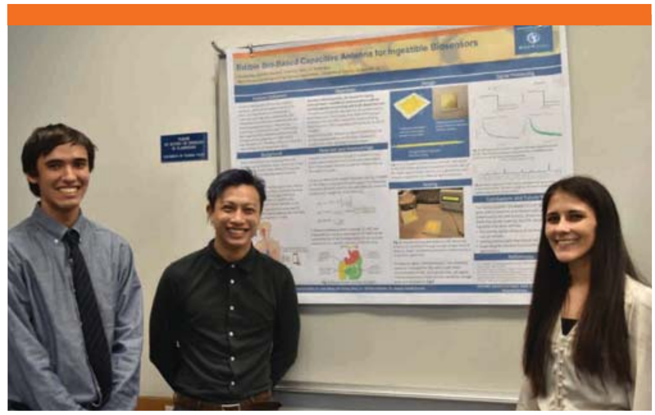
The substrate material was wafer paper, a potato starch product commonly used for cake decorations. Two edible gold foil sheets were adhered to either side of the substrate with a glycerol and water solution. The glycerol solution served as both an adhesive and a plasticizer, which made the antenna more flexible and easier to encapsulate in a pill.

Eudragit FS-100, a medical-grade polymer, was used as a surface coating for the substrate to increase the durability and functionality of the antenna. This delayed-release polymer dissolves only above a pH of 7, making it ideal for protecting the device from the acidic environment of the gastrointestinal tract.

To test the signal transmission, we connected prototype antennas to a function generator and measured their signals with a digital oscilloscope. We also explored Fourier transformation algorithms to process the signals and isolate targeted frequencies.

The tests demonstrated that the antenna can consistently produce high-frequency signals and receive signals within the near-field range. Edible electronics, such as food-grade antennas, are expected to open up new applications at the junction of agricultural and biological engineering.

Veronica Tami and Spencer Serrano, Undergraduate Students, Department of Biological Engineering, University of Florida, Gainesville, USA, serranos@ufl.edu.



Edible antenna team members (*left to right*) Spencer Serrano, Cuong Dao, and Veronica Tami.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The Last Mile from Classroom to Workforce

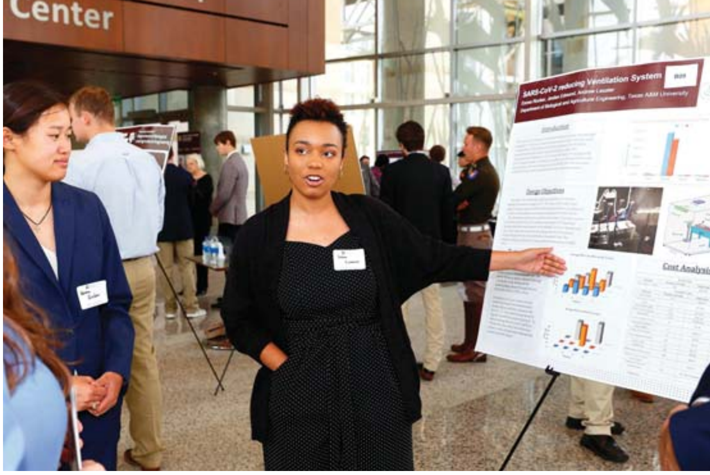
Rabi Mohtar, P.E., Russell McGee, P.E., and Patricia Smith

In the Department of Biological and Agricultural Engineering at Texas A&M University, both of our undergraduate degree programs, Biological and Agricultural Engineering (BAEN) and Agricultural Systems Management (AGSM), require a two-semester capstone sequence that provides a comprehensive exercise in real-world problem-solving. For both majors, the open-ended projects allow the students to apply the knowledge they gained throughout the curriculum.

The 2022 capstone program included a total of 22 projects in BAEN and AGSM. Collectively, these projects reflected the wide variety of applications that our students are prepared for when they enter the workforce. Five of the projects were suggested by clients in Lebanon, Nicaragua, and Ecuador. International projects allow the students to learn about cultural impacts, foreign standards and regulations, and differences in personal and professional conduct.

Before COVID, students traveled overseas to meet with international clients, visit the research sites, and understand the local constraints. COVID has forced the students to learn new ways of communicating and gathering information. One such project involved a wastewater treatment system for a dairy in rural Lebanon. Here's how one of the team members described the project:

> *"This project had a unique set of challenges. Because our sponsor was in another country, we were not able to meet with her in person, which forced us to communicate through weekly Zoom meetings. While working remotely, we had to understand the economic, social, and political conditions in Lebanon. The economic situation in Lebanon is unstable, and the main constraint for this project was cost. If materials were too expensive or unavailable, our design would fail.*
>
> *"The instability of the energy system in Lebanon was also a major constraint. A source of renewable energy is imperative for the communities that implement this project. The conditions in Lebanon created a big contrast with the domestic projects of the other teams. The economic crisis and its effect on the Lebanese people motivated us to create the best possible design. We're proud that we were able to apply our engineering skills to a project that can really help people."*



BAEN student Jordan Edmond presents her team's design to improve air quality in hospital rooms.

The culmination of the capstone course is the Capstone Event, where the students present posters and prototypes in a conference-like setting. A panel of volunteer judges interacts with the teams and selects the best projects based on innovation, communication, and professionalism. Gold and silver prizes are given to the top two projects in both majors.

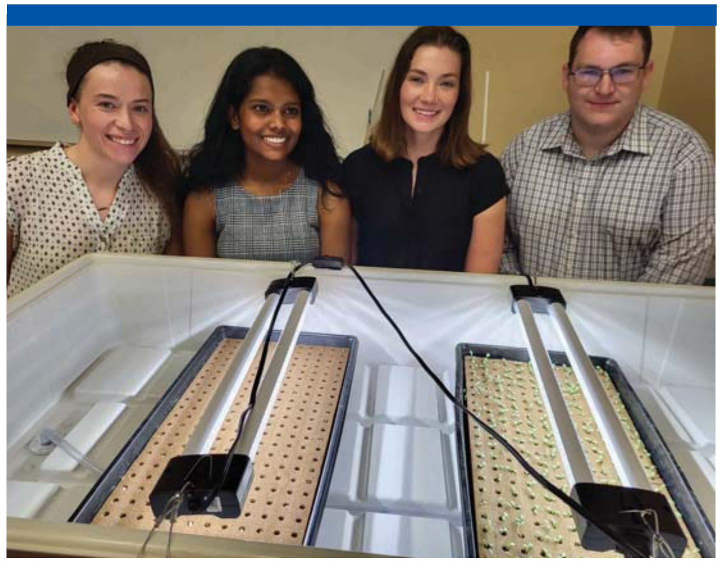
This year's BAEN gold prize winner was "A Vibration Monitor for Predictive Maintenance of Motor-Driven Equipment" developed for Anheuser-Busch. Last July, this team was selected to present their design in the AGCO Student Design Competition at the ASABE Annual International Meeting. The AGSM gold prize winner was "Packaging Coating to Increase Shelf Life of Fresh Produce" developed for Microgreens Chakra, a company that promotes the nutritional value of fresh produce.

ASABE member Sam Pyka demonstrates a device for removing plastic contamination in the cotton ginning process.

ASABE Fellow Rabi Mohtar, P.E., Professor, **ASABE member Russell McGee, P.E.,** Instructional Assistant Professor, and **ASABE Fellow Patricia Smith,** Professor and Head, Department of Biological and Agricultural Engineering, Texas A&M University, College Station, USA, patricia.smith@ag.tamu.edu.

Capstone Students Design a Teaching Tool for High-Tech Agriculture

Michael Peterson and Alicia Modenbach



(*left to right*) **Kelsey Greenwell, Madhu Sekar, ASABE member Keelie Carter, and Ben Shacklett,**

Climate change and extreme weather are threatening agricultural production. Some of the most productive land in North America is facing historic droughts, while other regions are dealing with unusually heavy rainfall. The agricultural community is also facing labor shortages, making it difficult to find skilled workers for increasingly sophisticated ag technology.

In the future, production of high-value crops will need to move closer to the water and to the workforce, even if that means our produce comes from the mountains of eastern Kentucky rather than the Central Valley of California.

To help grow the workforce of the future, the University of Kentucky is collaborating with AppHarvest, a developer of indoor agriculture. AppHarvest has invested heavily in teaching farms, made from shipping containers, to introduce high school students to controlled-environment agriculture. This high-tech production method will require skilled workers, and early introduction to the technology can raise awareness of this career path.

A senior design team in the University of Kentucky's Department of Biosystems and Agricultural Engineering (BAE) is working on developing low-cost, robust training equipment that can be implemented in high school ag tech programs.

Specifically, existing control and nutrient-dosing systems are well-suited for students, but looking "under the hood" of these systems requires a different set of technical skills. By developing tools that allow high school students to modify these systems, the BAE team is helping to build an ag workforce that can develop and maintain these systems, and thereby improve the productivity and sustainability of global agriculture.

Four BAE seniors worked with Hunter Jarosz and Molly McKinney, Ag Tech Program Coordinators from AppHarvest, to develop open-source software and design a dosing system for the container farm's hydroponic system. The BAE students use a Raspberry Pi computer and the I2C protocol to control dosing pumps, relays for lights and circulation pumps, and an array of sensors to monitor the system.

The entire electronic system can be accessed and controlled through a web browser, and the code is available and modifiable, providing a comprehensive learning experience for high school students. Documentation of the design, including wiring diagrams, piping and instrumentation diagrams, and code are available on the project website.

The specific goal was to develop a low-cost, modifiable teaching tool. The larger goal is to encourage the next generation of engineers at the intersection of agriculture and technology.

ASABE member Keelie Carter reflected on her capstone project experience: "This project made me more interested in growing plants of my own, and applying my controlled-environment specialization in greenhouses." The other three BAE students—Ben Shacklett, Kelsey Greenwell, and Madhu Sekar—all became more involved in automation, coding, and control systems through their capstone experience.

> "The students learn much more when they work on a project that can address a real need in the community, and their project can have a much larger impact."

"These kinds of projects are the most fun to watch," said **ASABE member Alicia Modenbach,** co-instructor for the capstone course. "The students learn much more when they work on a project that can address a real need in the community, and their project can have a much larger impact."

ASABE member Michael Peterson, Professor, and **ASABE member Alicia Modenbach,** Lecturer, Department of Biosystems and Agricultural Engineering, University of Kentucky, Lexington, USA, mick.peterson@uky.edu, alicia.modenbach@uky.edu.

All the BAE senior design projects can be found at https://www.engr.uky.edu/node/7221. The website for AppHarvest's automated nutrient dosing system can be found at https://sites.google.com/view/baeseniordesign-appharvest/home.

UNIVERSITY OF KENTUCKY

A Multi-Disciplinary and Multi-University Capstone Experience

Jeffrey Catchmark and Megan Marshall

Students from different disciplines and universities working on interconnected projects—this was the capstone format proposed by **ASABE member Daniel Ciolkosz,** one of our colleagues in Penn State's Department of Agricultural and Biological Engineering. In 2020, Dan and his collaborators at Virginia Tech, West Virginia University, and SUNY College of Environmental Science and Forestry received a USDA-NIFA grant to fund the Mid-Atlantic Sustainable Biomass for Value-Added Products Consortium (MASBio).

One goal of MASBio is to support undergraduate projects in which student teams work together to achieve a larger objective related to the grant. In the 2021-2022 academic year, student teams were asked to develop a concept for a mobile biochar production unit that could be moved to different logging sites. The biochar would be used as a soil amendment for reclamation of marginal land.

Each team focused on a different aspect of the project: site development and economic analysis (West Virginia), feedstock availability and logistics (Virginia Tech), environmental impact assessment (SUNY ESF), and engineering design (Penn State). The Penn State team consisted of four biological engineering students, **ASABE members Jacob Haskins, Joseph Marino, Brendan McGinn, and Yarin Shmilovitch,** who worked on the project throughout their two-semester capstone experience.

Woody debris from a flail delimber at A.M. Logging in Centre Hall, Pennsylvania.


Capstone student and ASABE member Jacob Haskins works on prototype fabrication.

In the fall semester, the Penn State team evaluated customer needs and generated design concepts. The team met with Wes Miller of A.M. Logging LLC in Centre Hall, Pennsylvania, for a first-hand look at how forest materials are harvested and processed. At the end of the fall semester, the team members presented their concept of a continuous pyrolysis process to produce biochar.

In the spring semester, the team performed lab pyrolysis tests using woody residue samples collected at A.M. Logging, they finalized the design, and they constructed a proof-of-concept prototype. The team leveraged skills from their prior coursework to complete mass and energy balances for the pyrolysis process and develop engineering drawings of the prototype.

The prototype was designed to operate manually with a screw auger to move woody residue into a heated chamber and then remove the biochar. Randall Bock, the ABE fabrication lab manager, trained the team on the tools, including a plasma cutter, TIG and MIG welders, bandsaw, and grinder.

The multi-university and multi-disciplinary capstone experience turned out to be a winning format. As Dan Ciolkosz explained, "Each team shared updates on its part of the project and provided feedback and information to the other teams. For example, the West Virginia team focused on the economics of project development and used costing and production information from the Penn State team as the basis for their modeling efforts."

The Penn State students agreed that they gained a lot from the experience. Brendan McGinn summarized the experience as follows: "Capstone was a great bridge between college and industry. It helped me become a more confident communicator and learn new approaches to open-ended problem solving."

As capstone instructors, that is exactly the outcome we hope for!

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UNIVERSITY OF ARKANSAS

Prize-Winning Designs

Scott Osborn, P.E. and Benjamin Runkle, P.E.

At the University of Arkansas, biological engineering capstone is a two-semester program in which student teams are paired with a client with a real engineering problem. The first semester is used to research the problem, including relevant technologies and analyses to support the design process. The second semester is devoted to producing a detailed design.

Over the past ten years, our capstone teams have done very well in ASABE design competitions, finishing in the top three nearly every year. Our students are eager to learn new things and tackle new problems. Nothing is more rewarding than watching these young people take on the big challenges that our world faces.

Team members (*left to right*) Juliana Newman, Nathan Bowman, Harrison Davis, and Noah Olson during their presentation on stormwater design for a residential development.

Team members (*left to right*) Ellie Kuhn, Aubin Payne, Andrew Daniels, and Alexis Barber during their presentation on the restoration of an on-campus lot.

The rapid growth in northwest Arkansas has created challenges for sustainable development. New construction has increased the region's impervious surfaces, thereby increasing the risk of flooding after rainstorms. These challenges provide the backdrop for two of this year's capstone projects. Last July, these two projects took first and second place, respectively, in the Gunlogson Environmental Design Student Competition at the 2022 ASABE Annual International Meeting.

Alternative Stormwater Design

Crafton Tull, a local consulting firm, tasked a student team with designing a drainage solution for a housing development in a clay-rich area in Rogers, Arkansas. The team consisted of **ASABE members Nathan Bowman, Harrison Davis, Juliana Newman, and Noah Olson.** They were advised by **ASABE member Benjamin Runkle.**

The team assessed several alternatives for managing stormwater runoff and the associated water quality issues. Ultimately, the team designed a permeable pavement system so effective that they were able to increase the number of developable lots by eliminating the need for a retention basin. The permeable pavement was also less expensive than a conventional sewer and basin approach.

Clinton Drive Lot Restoration

The second project had the University of Arkansas as a client. This team developed solutions for a hillslope site on the campus that was located amid dormitories, classroom buildings, and rental houses. The team consisted of **ASABE members Alexis Barber, Andrew Daniels, Ellie Kuhn, and Aubin Payne** and was also advised by Benjamin Runkle.

The students surveyed the site to get an accurate measure of the topography. They also performed surface hydrology experiments, which confirmed that they should assume zero infiltration due to the clay soils. The team needed to accommodate a variety of stakeholders, including landscaping crews with limited time, bike trail users with an interest in sloping paths, and site managers who complained that avid football fans often try to park on the flat areas.

"Nothing is more rewarding than watching these young people take on the big challenges that our world faces."

Balancing these needs required some ingenuity. The team hid boulders, as parking barriers, behind native vegetation that would generate bank stability and slow stormflow. They also designed stone and vegetation channels to route flow offsite without eroding the underlying soils. Visit our campus to see how these solutions have been implemented!

ASABE member G. Scott Osborn, P.E., Associate Professor, and **ASABE member Benjamin Runkle, P.E.,** Associate Professor, Department of Biological and Agricultural Engineering, University of Arkansas, Fayetteville, USA, gsosborn@uark.edu.

Holy Inaugural Senior Capstone, BATMan!

John Linhoss, Jeremiah Davis, P.E.,
Mark Dougherty, P.E., and Oladiran Fasina, P.E.

Auburn University's Department of Biosystems Engineering (BSEN) has a long history of producing engineering graduates. Recently, the department added an additional focus: training non-engineering students through its Biological and Agricultural Technology Management (BATM) program. As the title of this article suggests, it's affectionately known as the "BATMan" program.

In 2019, BATM was approved as a new degree program administered by BSEN. Like many other agricultural technology programs, the goal of BATM is to produce graduates who can use technology to solve problems. "I've been very impressed with the students in the BATM program," said department head Oladiran Fasina, "They've added an exciting new perspective to the BSEN department."

In spring 2022, the first cohort of BATM seniors (n = 3) completed a semester-long capstone project. The BATM program is growing, and future classes won't be so small. In the meantime, the three students really appreciated the intimate size of their class. Adam Lenhard reflected on what he enjoyed about the class: "The fact that it was just the three of us made the project much easier to complete. There was never a lack of communication, and everyone did their fair share."

BATM students (left to right) Baylor Arnold, Adam Lenhard, and Josh Etherton display the iterations of their light box design.

For their capstone project, the students used modeling software and 3D printing to create a ceiling-mounted light box for commercial poultry houses that can easily replace the conventional fixtures, which often break. Growers often do not replace broken light boxes because of the time and labor required. The light boxes support keyless sockets and light bulbs, so a cracked or broken box can create an electrical hazard and a fire risk.

The students printed four iterations of their light box and evaluated the robustness of the design. They also compared the replacement time for their design to the conventional fixture and used UV-sensitive dye to reveal the ability of their design to resist water intrusion during a simulated poultry house washdown.

Josh Etherton reflected on the capstone experience: "I learned about the design process as well as how to perform group work in a professional way. I also learned how to conduct research and the importance of keeping a timeline of goals and milestones when dealing with a large project."

Overall, the inaugural senior capstone class for the BATM program was a success. The three students took ownership of their project and were proud of the final product. Baylor Arnold summed it up well:

"I took everything I learned in BATM and applied it to a real project. I got to spend time with people I know well and complete a project that we all enjoyed. The project was a perfect combination of design and implementation. BATM is a hands-on major that deals with technology and field work, and this project demonstrated that."

Adam Lenhard performing a water intrusion test that simulates a poultry house washdown.

ASABE member John Linhoss, Assistant Professor,
ASABE member Jeremiah Davis, P.E., Associate Professor,
ASABE member Mark Dougherty, P.E., Associate Professor,
and **ASABE Fellow Oladiran Fasina, P.E.,** Professor and Head,
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ASM Students Design and Build Portable Livestock Shelters

Guy Bates, P.E.

The Agricultural Systems Management (ASM) program at Cal Poly uses "Learn by Doing" to provide hands-on education in agricultural technology combined with practical business and management training. The program culminates in a year-long capstone project during which students apply their knowledge and skills to real-world problems.

During the 2021-2022 academic year, teams of six or seven ASM students worked to design, build, test, and deliver portable shade structures for Creston Enterprises, LLC. The client operates a 2500-acre ranch in Creston, California, using sustainable, regenerative, rotational grazing practices to raise livestock and improve soil and ecological health while generating livestock products.

Creston runs cow-calf, lamb-ewe, and nanny-kid grazing units mixed in a single paddock to be grazed for one day, and then the animals are moved to the next paddock. The ranch has a Mediterranean climate characterized by hot, dry summers with temperatures that can exceed 110°F.

The project's goal was for each team to provide a portable support structure that could be moved daily with the livestock. The minimum requirements were:

- 750 square feet of shade.
- 250 gallons of water.
- An accessible water trough or approved alternative.
- Mineral and salt block holders.
- Towable using a John Deere 333G skid steer.
- Easy to set up, take down, and move daily.
- Suitable for local conditions.

In the fall, the teams used their design and project management skills to ensure they could provide a solution that would meet the client's needs on time and within budget. Design started with a literature review and brainstorming with hand-drawn sketches. The teams then progressed through several design iterations, calculations, and sizing of the structural elements, ultimately leading to final CAD drawings. Project management tasks included the development of schedules, Gantt charts, and cost estimates. While each design was different, all teams started with the running gear for an E-Z Trail 860 hay wagon.

ASABE member Luiz Lopez (*front*), Julian Torrez (*on the ladder*), and Edwin Anaya (*back*) working on the structure.

In the winter, the teams ordered materials and began fabrication. Tasks included cutting, welding, building hinges, and installing hydraulic cylinders and components. The teams also began to practice active project management by monitoring the project budget and schedule and controlling the work to remain on track.

In the spring, the teams completed fabrication and testing. They also prepared a safety and operation manual and a short video presentation before delivering the finished product to the client.

The ASM program at Cal Poly prepares students to understand, design, and operate the technological systems used in modern agriculture, including energy and power systems, water management tools, mechanical and electrical systems, robotics, and more. Many ASM graduates go on to work as water specialists, project managers, construction managers, and agricultural operations managers.

Thanks to capstone projects like these, ASM students have the opportunity to apply what they learn in the classroom to real-world problems. As a result, ASM graduates are ready, from day one, to make an immediate impact on the world around them in their careers and throughout the rest of their lives.

A completed prototype of the towable livestock shelter.

ASABE member Guy Bates, P.E., Assistant Professor, Department of BioResource and Agricultural Engineering Department, Cal Poly State University, San Luis Obispo, California, USA, gwbates@calpoly.edu.

Hands-On Learning at the University of Illinois

Travis Johnson

Hands-on project-based learning is essential to the Engineering Technology and Management for Agricultural Systems (ETMAS) program at the University of Illinois. The ETMAS program prepares students to be problem solvers for clients involved in the application, management, and marketing of engineering technologies.

To equip our ETMAS students with real-world project management skills, we developed the ETMAS Capstone Experience in 2021. This course serves as a test-run for students before they enter the workforce. Prior to the semester, in collaboration with industry partners and faculty, we identify appropriately challenging projects in agriculture, construction, and environment that can be completed in one semester.

During the first week of class, individual students apply to the various projects. Teams are then selected based on student interests, experience, and skills. As an example, the NovaCase team was tasked with helping industries deal with the effects of COVID-19. Another team, Illini Grain, worked with a grain company to develop an improved method for measuring grain in large bins.

Next, the teams are asked to research similar projects and describe how they plan to avoid the possible challenges they anticipate. The NovaCase team suggested that their topic was so broad that they might spend too much time determining a plan, while the Illini Grain team noted that dust in grain bins presents a challenge because they planned to use LiDAR sensors to measure the grain surface.

The teams then present their design proposals, including budgets and technical diagrams. NovaCase submitted a plan to create a phone-sanitizing box using UV light, while Illini Grain decided to optimize the methodology that the grain company uses and provide a mathematical model to more accurately measure grain.

The NovaCase team ran their motion- activated phone-sanitizing box through several trials, ensuring that the UV light deactivated a sufficient number of viruses. The Illini Grain team made many site visits to test the feasibility of their methodology and built a demonstration and testing unit.

To conclude the course, the teams present and defend their prototypes on Spark Tank Day. A panel of representatives from industry and academia grill the teams about their prototypes and business plans. The students then vote to determine the best team projects.

In addition to the semester-long projects, the teams participate in in-class competitions throughout the semester. The activities include building a spaghetti and marshmallow bridge, egg-carrying glider planes made from simple materials, and balloon-powered cars. These activities help the students understand the dynamics of working in teams.

To simulate the real-world challenges of industry settings, the instructor introduces additional complications, such as unexpectedly requiring the teams to swap their half-built balloon cars with other teams, or shortening the time they have to build.

Overall, the course challenges the students in ways they will be challenged in their careers. The students seem to appreciate the opportunity. As one student wrote, “The most useful experience this course gave me was working hands-on with an actual project. In most classes, you work on an imaginary project, but in this class, you actually get to build it!”

ETMAS Senior Kerim Lakota assembles an RC jet turbine test stand. This test stand will be used to test jet biofuels created in the ABE department.

NovaCase team members Ololade Ayoola, Tim Verlinsky, Kevin Zhagui, and Alex Brown proudly showing their motion-activated phone-sanitizing box after coming in first place on Spark Tank Day.

ASABE member Travis Johnson, Academic Advisor and Instructor, Department of Agricultural and Biological Engineering, University of Illinois, Urbana-Champaign, USA, travisj2@illinois.edu

ABE Seniors Improve Poultry Farm Safety and Efficiency

Sarah Hays

IOWA STATE UNIVERSITY

The research pursued in Iowa State University's Department of Agricultural and Biosystems Engineering includes power machinery, occupational safety, animal welfare, and many other topics. For four seniors in the ABE department—Austin Marshek, Max Lindgren, Logan Heims, and Hunter Frerichs—their senior capstone project combined several of these concerns: livestock, machinery, and safety.

The Environmental Health and Safety (EH&S) team at Iowa State reported a hazardous device at the Robert T. Hamilton Poultry Teaching and Research Facility. During a visit to the facility, the students were introduced to the problem: the hand-cranked winch used in the feed delivery system was a safety hazard for the poultry farm workers. This winch was used to lift the feeders temporarily so that the workers could clean the area occupied by the chickens.

Chicken feeders attached to a pulley system.

According to EH&S, the winch was located at head level for many of the workers, creating a risk of head injury. In addition, the winch carried so much weight that it was beginning to detach from the wall. It was up to the capstone team to solve this problem.

The hand-cranked winch used to raise and lower the feeders.

"The winch was pulling away from the wall and breaking because of the weight of the feeders, and most of the workers are not tall enough to pull the handle," Marshek said. "Our goal was to redesign the whole area so that the winch would no longer be pulling away from the wall and would be more structurally sound. We could then get rid of the protruding handle so it would no longer be a safety hazard."

Part of their design included increasing the size of the metal plate that the winch was attached to and thereby distributing the weight over a larger area. The larger plate reduces the chance of the winch pulling away from the wall. The team also added stronger bolts to help with the weight distribution and adjusted the handle. The cost was very affordable—about $200—to completely renovate the winch.

When the team was assigned this project, their initial goal was to improve the design of the winch. The team also calculated how many new winches would be needed in the facility and planned to install the new winches. Once the team has installed their new design, it can be implemented across the facility, and even across other facilities in the poultry industry.

> "This is a classic example of thinking that we knew what the solution would be, but after digging into it, we found more problems, which led to a different solution."

Going into this project, the team wasn't expecting to do a full-cycle redesign like this. However, sometimes one problem can lead to another, which then leads to an even better solution. That often happens in engineering, according to the team's advisor and professor, **ASABE member Gretchen Mosher.** "This is a classic example of thinking that we knew what the solution would be, but after digging into it, we found more problems, which led to a different solution," Mosher said. "Problems like this can inspire real creativity. That's the value of this experience."

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