Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025
Paper ID #45623

Engagement in Practice: Lessons Learned from Partnering with a Local Regenerative Farm in a Mechanical Engineering Capstone Course

Ms. Shoshanah Cohen, Stanford University

Shoshanah Cohen is the Director of Community Engaged Learning for Engineering at Stanford University, working with faculty to incorporate community-engaged projects in their courses. She co-teaches Stanford's mechanical engineering senior capstone course sequence.

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Abstract

This paper explores how students in Stanford University's mechanical engineering capstone course partnered with a local regenerative farm to design an innovative mobile fencing system, using a lateral movement irrigation system (LMS) in an unconventional way, while addressing real-world challenges in engineering design and community collaboration. Student teams in ME 170 explore the needs of users and look to understand the cultural and societal context for their projects, with student outcomes targeted in accordance with ABET requirements for baccalaureate degree programs. The local farm, Pie Ranch, manages a regenerative farm and education center that cultivates health and justice in the food system. As part of its operation, Pie Ranch farms pastured laying chickens, which need consistent access to fresh grass and the food sources it contains, as well as protection from predators. Pie Ranch uses electrified netting fencing to deter predators and contain the chickens as part of a rotational grazing program. This netting must be disassembled and reassembled before the chickens can be moved to a new area of the pasture. The process to uninstall and reinstall fencing is manual and can take several hours each day. The student team was tasked with developing a proof of concept that uses the power of an LMS to deploy a mobile fencing solution for a contained grazing area. The resulting design features a suspended netting system, attached to a cantilevered frame secured to a 135' LMS irrigation pipe. In this paper, we present a summary of the students' approach to managing expectations via detailed calculations, modeling, and scaled prototypes for a community partner whose vision included reliance on future infrastructure to be used in a novel and unexpected way.

Introduction

Community engaged learning (or service-learning) enhances student education by linking theory to practice and classrooms to communities [1][2]. Partnering with community organizations contextualizes engineering, broadens perspectives on who engineers can be and serve, and supports diverse student retention, particularly for those motivated to create impact [3].

Well-structured service-learning fosters deep learning and personal growth and is considered a powerful educational and social intervention tool. Instructors play a key role in developing partnerships in engineering community engaged courses. Eby [4] acknowledges that "individual faculty often carry the additional workload and cost of incorporating community partners into courses," often with minimal institutional support. Campus centers for public service can provide essential resources to sustain these efforts.

Mechanical Engineering Design: Integrating Context with Engineering (ME 170) is the culmination of Stanford University's mechanical engineering BS program and immerses students in a team-based engineering design challenge working in a team of four [5]. Projects tackle societal issues such as energy, food security, transportation, and health. Over two quarters, students iteratively define needs, establish design requirements, prototype, test, and refine solutions, gaining skills in design, teamwork, project management, and ethical evaluation. Funding comes from industry affiliates and community-engaged learning grants provided through the Haas Center for Public Service, with each team guided by an experienced project coach.

Table 1: ME 170 Learning Objectives

ABET Student Outcomes [6]	ME 170 Objectives
Ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental and economic factors.	Deliver an engineering system addressing a real-world problem, using (1) the engineering analysis and design skills learned through the first three years of their undergraduate education, in conjunction with (2) the engineering design process taught in ME170A/B. Solutions must be tested against design requirements.
Ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives	Work as part of a team to design and develop an engineering system. Students will leverage their technical expertise, while relying on and collaborating with teammates with different areas of expertise, to engineer a system. They will learn industry practices for engineering development and project management skills.
Ability to recognize ethical and professional responsibilities and make informed judgments which consider the impact of engineering solutions in global, economic, environmental, and societal contexts	Assess the impact of engineering solutions. Students will work on projects associated with pressing needs of human society, and broaden their perspectives to consider their ethical roles as engineers working on these projects.
Ability to communicate effectively with a range of audiences, ability to acquire and apply new knowledge as needed, using appropriate learning strategies.	Learn and apply professional communication skills, including oral presentations, written deliverables, and critical listening and feedback. Students will use communication skills to (1) determine the specifics of the problem they are solving, and (2) assess how best to communicate the problem they are solving and their proposed solution to non-technical audiences, while (3) developing skills for communicating complex topics to both peers and experts.

Project Background

Pie Ranch is a working regenerative farm located approximately 30 miles from Stanford University. The farm has successfully collaborated with Stanford on projects in multiple community engaged learning courses. Regenerative farming is a holistic agricultural approach focused on improving soil health, enhancing biodiversity, and increasing resilience to climate change [7]. One of its key practices, rotational grazing, requires moving livestock frequently to prevent overgrazing and promote pasture recovery. This process relies on flexible fencing systems that can be moved on a regular basis.

Pie Ranch raises pastured laying chickens, which require fresh forage and predator protection. Electrified netting fences around the chicken flock are used to deter predators and contain the chickens within a designated area as part of the rotational grazing program. As the chickens are moved, the netting must be disassembled and reassembled.

Netting systems include the netting itself, posts needed to create the fenced area, and a fence energizer; they are purchased as a roll of netting with the posts built in. To install the fence, the netting is unrolled into a series of folded pleats, each attached to two posts. After the first post is inserted into the soil, the netting is unfolded along the fence line, the posts are inserted, and the netting is tied to the posts. The fence energizer is then attached before moving livestock into the enclosure. The process to uninstall and reinstall fencing is manual and can take several hours each day. If no staff is available, the pasture may develop "hot spots"—areas of overgrazing which do not provide adequate nutrition and compress the soil to a degree that planting is not possible—and must supplement with purchased chicken feed.

At Pie Ranch, the chicken pasture is also a source of animal feed, as it is planted with cover crops, such as clover, alfalfa, and wheat. As chickens are gradually moved across the pasture, they cultivate it and their manure provides fertilization for the next crop. Chickens eat the shorter plants, but are more focused on the insects and worms that live among them, thus providing a natural pesticide.

Pastures must be irrigated so that they do not become dormant. There are many methods for pasture irrigation, including flooding, pivot systems, and pod lines. Pie Ranch planned to purchase a lateral movement irrigation system (LMS) to be delivered and installed during the first quarter of the course sequence. An LMS is self-propelled and applies water to a field through a pipe system mounted on two towers. The towers support the span of pipe and contain drive mechanisms and wheels. Emitters are attached at outlets along the pipe, watering the field from above. Both towers move at a slow and constant speed up and down a field. The system requires power to pump water through the span and to move the machine itself. Lateral movement irrigation systems have several advantages: They can apply a prescribed volume of water to match crop needs; they have relatively low labor requirements; and they reduce wasted water significantly [8].

Pie Ranch envisioned a moveable chicken enclosure attached to the LMS that can be easily moved as a unit for rotational grazing, without the need to uninstall and reinstall the fence piece by piece. As the LMS traverses the field, chickens would be nudged along, providing natural pest control, fertilization, and cultivation. The student team was tasked with a novel engineering challenge in designing, building, and testing a scaled prototype of the integrated system [9].

Design Approach

Students in ME 170 are evaluated on the quality of engineering demonstrated in the final product, including the degree to which the design satisfies a series of user and engineering requirements, as established through calculations and testing. The student team followed a structured engineering design process over the two quarters that involved:

- Conducting a needs assessment with the partner liaison to understand functional requirements, such as size, safety, and compatibility with other equipment.
- Brainstorming potential solutions, including sketches and concept models, to explore ways the farm's equipment could be adapted for fencing deployment.
- Prototyping and iterating on designs using low-cost materials and testing to ensure feasibility under simulated farming conditions.
- Identifying a single design concept to pursue for the remainder of the course.
- Fabricating a functional, higher-fidelity prototype.
- Developing a formal test plan and identifying design refinements based on analyses of test results.

The student team first developed a set of high priority user requirements focused on providing adequate grazing space and protection from predators. These user requirements translated into ten engineering requirements (Table 2).

Table 2: High Priority User and Engineering Requirements

User Requirements		Engineering Requirements	
UR-1	Chickens must be protected from predators	ER-1A	Fence must be at least 8’ high
		ER-1B	The fencing must receive 0.5 Joules of power per 165’ of fencing
		ER-1C	Fence must maintain contact with ground at all times
UR-2	Fencing solution is connected to an LMS	ER-2A	Fencing enclosure is designed to interface with an LMS
UR-3	Fencing solution is safe to operate, both while in motion and while stationary	ER-3A	Bending force (force perpendicular) applied on one a-frame member of the LMS must not exceed 2.7 kN
		ER-3B	Moment applied to the LMS by the fencing enclosure must not exceed 51.06 kN-m
		ER-3C	Fencing snags must not exceed 4.45 kN (1000 lbs) in force
		ER-3D	Fence and attachment mechanisms are made from corrosion-resistant materials to avoid rust and failure due to corrosion
UR-4	Chickens must have sufficient space to graze and live	ER-4A	Each chicken is provided with a minimum of 25 ft^2 / day
		ER-4B	The fencing enclosure can support 100 chickens

ME 170 teams are challenged to brainstorm a minimum of 25 design concepts, which are then grouped by their various features and assessed against high priority requirements after comprehensive engineering analysis. Teams then select three designs to develop further. The downselected concepts are shown in Figure 1.

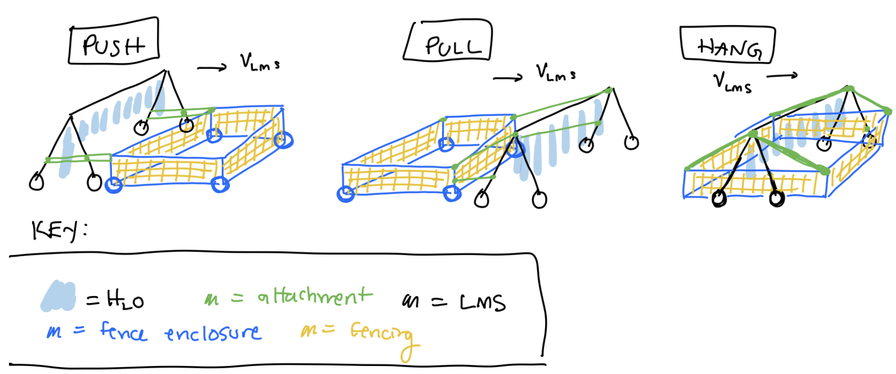

Figure 1: “Push”, “Pull”, and “Hang” design candidate sketches

To gain insight into which of the three would best satisfy the engineering requirements, the team built a miniature low fidelity model of an LMS using foam core and wood and created three fence attachments to visualize the functionality and identify any immediately obvious shortcomings. The “Push” design was selected for further development as it was the only design in which pasture irrigation followed the chickens’ path. The team then built a larger scale model of an LMS and fencing frame using PVC pipes to provide a sense of the scale and structure of an LMS and tested potential failure modes, including tipping, shearing, and fencing material failure.

Challenges

Pie Ranch had anticipated having the equipment installed by the second quarter, but funding delays slowed progress. Without access to the planned LMS equipment, the team faced challenges—low-fidelity prototypes were sufficient for concept evaluation but fell short for empirical testing. Given that LMS equipment is custom-configured for specific applications, locations, and terrain—and this use case was unprecedented—determining specifications proved difficult. Local farm equipment distributors were hesitant to offer theoretical configurations for such an unconventional application, and infrequent communication from the project liaison further complicated the process. As one student reflected at the end of the first quarter, “I’m worried that we will not fulfill the project's requirements and therefore not contribute the value that the liaison and organization were hoping for.” To keep moving forward, the team consulted their project coach and project liaison and agreed to proceed without LMS access, creating a CAD model (Figure 2) based on assumed materials and geometries and a quantitative model to allow refinement of specifications once the equipment was in place.

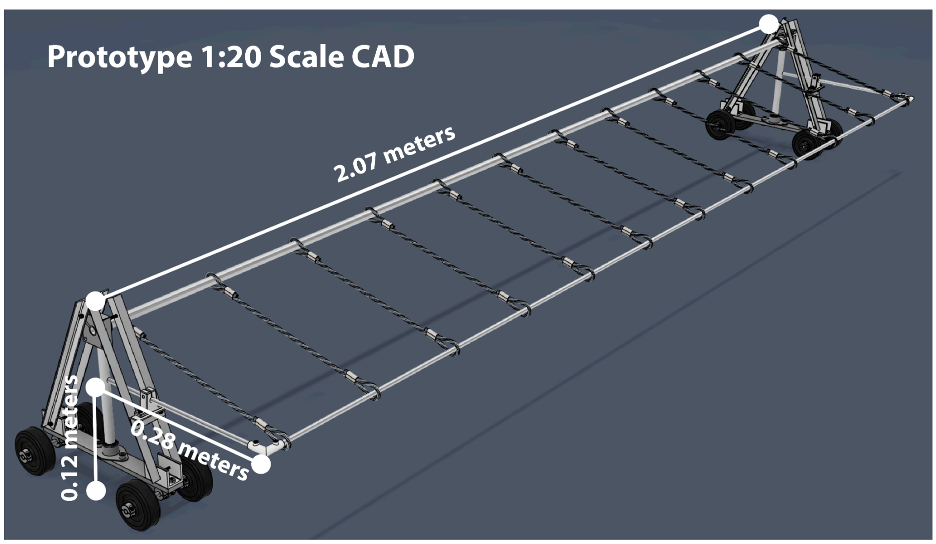

Figure 2: Final 1:20 scale CAD model for the integrated LMS/moveable fence system based on the original “Push” design concept

The team shifted focus to developing a physical scaled model (Figure 3) of the LMS/fence system to demonstrate the integrated concept. Based on the “Push” design, the resulting configuration features a suspended netting system attached to a cantilevered frame secured to a 135’ irrigation pipe. Pie Ranch expressed their gratitude for the scale model and requested to keep it as a demonstration aid for discussions with prospective donors.

Six months after completion of the project, Pie Ranch was successful in securing a grant to cover the costs of procuring an LMS, noting that the model was instrumental in helping grantors visualize farm equipment being used in a novel and unexpected way.

Figure 3: The final 1:20 scale physical prototype was built using the same dimensions as the CAD model shown in Figure 2

Conclusions

Project-based learning is a powerful approach in engineering education, but developing projects that balance educational goals with meaningful community impact can be complex. Clear expectations and outcomes, established collaboratively between instructors and project partners, are important for supporting student success, as capstone courses are primarily educational experiences [10]. Having necessary infrastructure in place before a project begins helps prevent delays and supports student momentum.

The long-term partnership with Pie Ranch has provided valuable continuity, allowing student teams to build on previous efforts, refine designs, and extend projects beyond a single course. Some students have even continued their work over the summer or after graduation, deepening their contributions and broadening their impact.

The LMS project highlights key lessons for future capstone work. While changes in project scope or new discoveries can lead to further learning, delays or shifting priorities from partners can create frustration for students. Open-ended engineering challenges foster inquiry and innovation, but prolonged ambiguity can hinder progress; projects dependent on future infrastructure should proceed only when detailed specifications are available in lieu of physical equipment.

Despite these challenges, students gained valuable experience in problem-solving, adaptability, and stakeholder collaboration. Their design, though theoretical, provided a proof of concept for repurposing equipment and strengthened skills in design, prototyping, and systems integration, with a continued emphasis on user needs and environmental sustainability. The final deliverable also supported the community partner's efforts to secure additional resources, paving the way for future collaboration.

Acknowledgements

The author wishes to thank capstone students J.R. Chou, Dominick Sangster, Frankie Sperka, and Denny Woong for bringing a valuable combination of engineering skills, perseverance, and humor to a challenging project, TA Nathaniel Barnard for his exceptional guidance, and Jered Lawson and Leonard Diggs of Pie Ranch for their continued partnership with Stanford.

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